THESIS ON NATURAL AND EXACT SCIENCES B120

Food Category Appraisal Using Sensory Methods

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any other degree.

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Abstract

Category appraisal is an industry-oriented scientific method where actual products rather than model systems are used. According to Moskowitz (2001), the category appraisal approach obtains ratings from products in the competitive frame. Munoz et al. (1996) noted that an appraisal usually involves product characteristics description and consumer response study to provide thorough understanding of the category. The food categories studied in this thesis were pomegranate juices, cheeses, and strawberry jams. The objective of the thesis was to appraise food categories in order to identify flavor profiles that are possibly successful or that characterize local identity.

In order to analyze the variation in flavor profiles of pomegranate juices, a lexicon development study was carried out. A lexicon of more than 30 attributes was developed for pomegranate juices category through profiling and clustering of 33 commercial samples purchased from Estonia, US, Thailand, and Spain. The lexicon was applied to compare flavor and aroma of industrial and fresh juices. The number of samples used in lexicon development enabled clustering of the juices for further analysis. The five flavor clusters were submitted to affective studies in four countries. According to these studies consumers' acceptance varied for some of the products studied, but the most disliked samples were similar in all countries. For example, a juice, which was characterized as sour, bitter, astringent, and fermented, was not liked anywhere, while a sample that was sweet in taste and cherry and candy-like in flavor, was liked by many consumers in all countries.

In order to appraise Estonian cheese flavor, the flavor properties of 36 Estonian cheeses were mapped and acceptance of two main flavor clusters was studied. All of the samples were characterized primarily with dairy flavor attributes. One cluster was composed of cheeses that carried sweet aromatics and the second cluster was more butyric and biting. The results showed a split in the acceptance of Estonian cheeses – some consumers liked younger cheese with milder and dairy properties and some liked aged cheeses that were stronger in their sensory properties better. The descriptive data was added to previous European cheese studies and a flavor map of 152 cheeses was created. The flavor map showed uniformity of most Estonian cheeses while French and Italian cheeses varied in their flavor profiles, suggesting either that consumers in Estonia tend to have less interest in various cheese flavors than French or Italian consumers or that manufacturers in Estonia simply have not produced a varied array of products.

Flavor, texture, and appearance of 25 strawberry jams were analyzed by descriptive sensory and instrumental means. The jams were clustered according to their sensory characteristics and correlations were found between sensory and instrumental measurements. The results showed three distinct clusters of jams which differed in color, flavor characteristics, and texture properties. However,

it was not possible to connect a flavor profile and a country of manufacture. Correlations indicated some common measurements such as Brix or dry weight may be replaced by applying sensory techniques or vice versa.

The novelty of the current thesis lays in the original research, findings and publications. The publications resulting from this thesis describe Estonian food and flavors, but also compare Estonian products to foreign products. The comparison of Estonian food flavors and characteristics to European and also US or Asian products helps in understanding differences between local and imported goods.

The results indicated some possible successful flavor profiles among pomegranate juices and strawberry jams; these were not connected to country of manufacture, but more likely to processing technology. Estonian cheeses, although uniform in their flavor, did not produce a unique flavor profile in comparison with cheeses manufactured in other European countries, and should be identified as familiar if exported to those countries. The studies confirmed category appraisal approach as appropriate in evaluation of food products.

List of Publications

The present dissertation is based on the following papers, which are referred to in the text by the following Roman numbers I-VI:

I. **K. Koppel** and E. Chambers IV. 2010. Development and Application of a Lexicon to Describe the Flavor of Pomegranate Juice. Journal of Sensory Studies 25: 819-837.

II. L. Vázquez-Araújo, **K. Koppel**, E. Chambers IV, K. Adhikari, A. A. Carbonell-Barrachina. 2011. Instrumental and Sensory Aroma Profile of Pomegranate Juices from the US: Differences between Fresh Juice and Commercial Juices. Flavour & Fragrance Journal 26: 129–138.

III. **K. Koppel**, L. Timberg, A. Salumets, T. Paalme. 2011. Possibility for a Strawberry Jam Sensory Standard. Journal of Sensory Studies 26: 71-80.

IV. **K. Koppel**, E. Chambers IV, D.H. Chambers. 2011. Flavour and Acceptance of Estonian Cheeses. Agronomy Research 9 (Special Issue II): 409-414.

V. **K. Koppel** and D.H. Chambers. Flavor Comparison of Cheeses Manufactured in Different Countries. Submitted.

VI. **K. Koppel**, E. Chambers IV, L. Vazquez-Araujo, L. Timberg, A. Carbonell-Barrachina, S. Suwonsichon. Pomegranate Juice Acceptance in Estonia, Spain, Thailand, and United States. Submitted.

In the appendix of this thesis, copies of papers I-VI have been included. Papers I-IV are reproduced with the permission from the publishers.

The Author's Contribution to Publications

Paper I: The author performed the experimental work, analyzed and interpreted the data, wrote the paper, and is the first author. The author also presented the results at the Institute of Food Technologists Conference 17-20 July 2010, Chicago, USA.

Paper II: The author performed sensory testing and participated in interpreting the results. The author is the second co-author of the paper.

Paper III: The author performed the sensory testing, analyzed and interpreted the data, wrote the paper, and is the first and corresponding author.

Paper IV: The author performed the experimental work, analyzed and interpreted the data, wrote the paper, and is the first and corresponding author. The author also presented the results at the Flavoure Conference 25-28 October 2011, in Tallinn, Estonia.

Paper V: The author analyzed and interpreted the data, wrote the paper, and is the first author.

Paper VI: The author performed part of the experimental work, analyzed and interpreted the data, wrote the paper, and is the first and corresponding author. The author also presented the results at the Pangborn Symposium 4-8 September 2011, Toronto, Canada.

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Abbreviations

AHC – Agglomerated Hierarchical Clustering

ANOVA – Analysis of Variance

CATA – Check All That Apply

CLT – Central Location Trial

HUT – Home Use Test

JAR – Just About Right

LAB – Lactic Acid Bacteria

PCA – Principal Component Analysis

PLS – Partial Least Squares

TDS – Temporal Dominance of Sensations

US – United States of America

QDA – Quantitative Descriptive Analysis

INTRODUCTION

Sensory analysis is used extensively in the category appraisal, quality control, product development, and import or export potential evaluation process of foods. The category appraisal approach obtains ratings from products in the competitive framework (Moskowitz, 2001). Munoz et al. (1996) noted that an appraisal usually involves product characteristics description and consumer response study to provide thorough understanding of the category.

The categories used in the approach can coincide with regional legislation or Codex Alimentarius standards (www.codexalimentarius.net); however, in most cases the category is narrowed down based on the objectives of the research. A category of food products comprises items that are similar in their purpose of use, such as chocolate bars, meat balls, white breads etc.

Sensory analysis tools explain the variations in appearance, texture, flavor, and aroma characteristics of the products, which may be linked to consumer satisfaction through hedonic or other assessments. Although packaging, price, product placement, and advertising are important in purchase process, "flavor" is the most important feature of food products (Rabino et al. 2007) and the key to repeating purchase decisions. Describing part of or the whole category of a food product in combination with surveys that determine consumer acceptance provide valuable insight for successful business decisions (Moskowitz et al. 2006).

Descriptive and discrimination methods provide information on similarities or differences among products and answer the question how and in what way the products differ within the category from one another. Describing product appearance, texture, flavor, and aroma using attribute definitions and reference materials, and evaluating the intensity of an attribute on a scale by trained panelists gives a full descriptive sensory profile of the product. Product profiles may be joined with evaluations given by consumers, such as liking or preference data. This makes understanding which kind of products are liked for which reasons, possible. Sensory assessment results often are linked to various instrumental measurements, for example instrumental aroma profiles, sugars or acids profiles, pH, or color values. These correlations are valuable for technologists and product developers in better understanding of the products by understanding the relationship between sensory and instrumental properties of those products and their ingredients, processes, and storage.

Category appraisal handles a considerable amount of data. The multivariate input data are difficult to visualize and interpret reliably without the use of statistical tools. For example, Principal Component Analysis (PCA), Partial Least Squares (PLS), etc. often are used for mapping products and their relations with attributes and other measurables. K-means clustering, Agglomerative Hierarchical Clustering (AHC), etc. are used for clustering products. Penalty Analysis is used to link product liking to attribute intensities within consumer study datasets. Analysis of Variance (ANOVA) is used for determining statistically significant changes between product profiles. These and other techniques have been described by Meilgaard et al. (2007), Lawless and Heymann (1999), and others.

The current study was part of an international collaboration project planned to provide applicable information and tools for food industries worldwide. Sensory analysis as a scientific tool is still used moderately in food production companies, especially in small- or medium-sized companies. However, sensory analysis tools can provide valuable and highly applicable information and thus, increase the competitiveness of food production companies. In addition, such methods introduced at R&D companies are valuable part of their business activities.

In order to develop and apply category appraisal methods, three categories of foodstuff - pomegranate juices, cheeses, and strawberry jams, were chosen.

Pomegranate juices represent a healthy drink category, the consumption of which is growing globally and is proven beneficial for diabetics, in prevention of heart disease, and as a valuable source of anti-oxidants as captured by Viuda-Martos et al. (2010). Before this work pomegranate juice studies that used category appraisal, such as a flavor profile for the whole category have not been published, nor have studies between fresh and processed juice flavor or aroma or cross-cultural consumer attitudes toward different flavor combinations been published.

While pomegranate juice flavors have not been described extensively, cheese is one of the most popular research objects of sensory scientists. Cheese represents a commodity consumed daily in Europe and US, a typical “savory” food, but also a traditional food in many countries. However, prior to this study in Estonia the locally manufactured cheeses category, its flavor and acceptance of flavor variations had not been profiled nor had its flavor been mapped and compared to cheese flavors from other European countries where cheese is a staple product.

Strawberry is one of the most used flavors in food products. Strawberry jam is a typical “sweet” food and thus strawberry jams as a category provides variability and possible insight for food producers worldwide. Available literature did not provide any information on strawberry jams category appraisal studies or whether strawberry jams manufactured in different countries carry similar flavor characteristics.

The objective of the thesis was to appraise food categories in order to identify flavor profiles that are possibly successful or that characterize local identity.

LITERATURE REVIEW

1.1 Product Development and Category Appraisal

Markets are flooded with new food products every year, many of which are likely to fail (Stewart-Knox and Mitchell, 2003). Rapid product development is aimed at gaining more market share by food production companies. The process of product development of food has been throughout described (Ulrich and Eppinger, 2003; Moskowitz , 2003; Moskowitz et al. 2006; Munoz et al. 1996; Meilgaard et al. 2007). Product development involves various activities from product formula fine-tuning to developing novel product concepts for new markets. The actual steps of development process greatly depend on the objective; however, in most cases characterization of products that are already on the market takes place. As was pointed out by Moskowitz (2003), product developers need to gather information of products already in the market before creating any prototypes or concepts.

In the case of appraising potential of a new concept the whole product category evaluation may be necessary for comparative purposes. The category appraisal approach obtains ratings from products in the competitive frame (Moskowitz, 2001). An appraisal usually involves product characteristics description and consumer response study in combination with statistical methods to provide thorough understanding of the category (Munoz et al. 1996).

The marketplace studies are related to import or export potential of the product, which can be evaluated by comparing product properties and product acceptance with the products available in the target market(s). Some cultures have a wide variety of product flavor combinations available while others are more conservative; products successful in one cultural background may not satisfy consumers in another which necessitates cross-cultural acceptance studies (Tuorila and Monteleone, 2009).

1.1.1 Descriptive Studies

Descriptive sensory analysis comprises a group of test methods that quantify the perceived intensities of the sensory characteristic of a product (Lawless and Heymann, 1999). It can be used on various food products and for solving different problems. Descriptive sensory analysis can be considered as one of the components of a category appraisal.

The Flavor Profile is a descriptive sensory analysis method developed by Caul (1957). The method involves highly trained panelists who characterize consensually the product by noting all of the flavors present and their intensities in the order of appearance. The Flavor Profile method is particularly useful in lexicon development studies because new attributes can be easily added, defined, and referenced when they appear in products the panel is seeing for the first time. The resulting language or lexicon is validated through sensory evaluation of the products. Because the results are based on panel consensus, the data cannot be analyzed using traditional single variable techniques such as analysis of variance, but can be analyzed using many multivariate procedures.

In 1960s Brandt et al. (1963) developed the Texture Profile method, which concentrated on the shape and force-related aspects of food. The method enables description of food texture and how it changes over the eating occasion. The attributes used are related to physical evaluation of food rheology and tactile properties.

Next, Quantitative Descriptive Analysis® (QDA) was developed by Stone et al. (1974). In QDA panelists give individual evaluations and this enables to use typical statistical methods such as analysis of variance to determine significant differences.

Sensory Spectrum™ (Meilgaard et al. 2007) method uses highly trained panelists and is supposed to provide a universal scale for any food product attribute. One problem with the method is that it assumes that panelists can make cross attribute comparison such as the level of orange flavor is as strong as the grape flavor in product X. In addition, reference materials required in this method could be difficult to obtain in some places.

The before mentioned methods are quite laborious and thus a Free Choice Profiling (Williams and Langron, 1984), a method that enables the use of untrained panelists to develop their own terms for describing the product, was developed. An even faster method, called the Flash Profile (Delarue and Sieffermann, 2004) has also been developed, where the panelists rate the products according to the attribute they see fit. The panelists use their own words and they should be able to describe different product properties.

A lot of researchers use a combination of the abovementioned methods, experience, and information available in the literature due to objectives, product, or financial reasons to create or adapt various methods to suit their needs.

Descriptive sensory analysis can be briefly described through the next steps: selection of the panel, developing a vocabulary, measuring intensities of attributes, and data analysis (Tuorila and Appelbye, 2005). In panel selection the researcher has to assure the panelists have the ability to taste and smell, and teach them to describe products. The panel size depends on the study, small panels usually use higher number of repetitions or more highly trained panelists. When developing a vocabulary, the panelists either develop part or the whole set of attributes to use in a product evaluation or learn to use an already existing vocabulary. This step usually comprises several group discussions on the attributes, definitions, reference materials, and evaluation procedure. Measuring intensities of attributes is the quantitative step of the process, where it is determined, how intense a certain attribute is in a product. This is usually done in repetitions and in a random order. Descriptive studies result in product profiles or descriptions in multivariate data format which may be difficult to grasp as is. Usually a mean score is calculated and the product flavor profiles are presented as spiderwebs (Fig. 1), which are useful in case of a small number of samples. Other possibilities include Principal Component Analysis (PCA), where a large number of attributes is transformed into a small number of principal components on a two-dimensional graph, and correlations among the dataset are visualized (Fig. 2); this method is more suitable in case of a larger number of samples and attributes, but the visual analysis can sometimes be misleading (Yenket et al. 2011). Statistical methods such as Analysis of Variance (ANOVA) provide the possibility to detect significant differences between products, or to check the reliability of the panel.

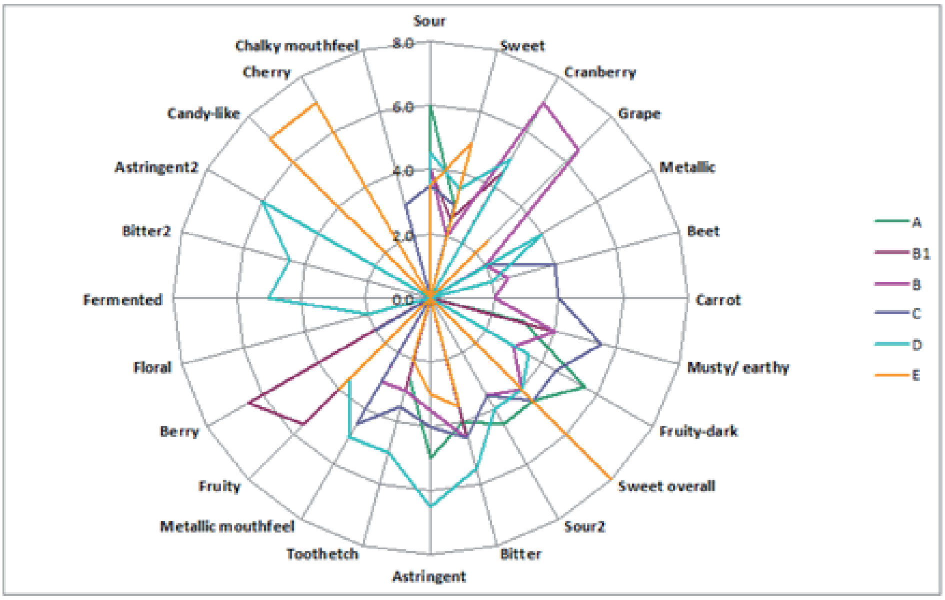

Fig. 1. Pomegranate juice flavor profiles (drawn according to data in Paper VI).

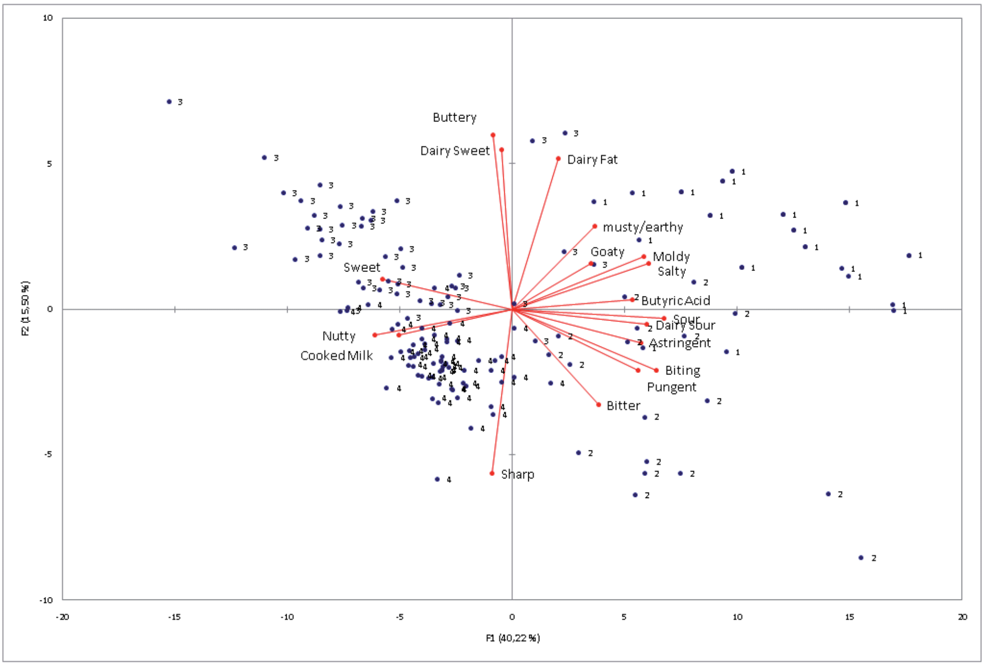

Fig. 2. PCA of cheese data (Paper V). Numbers 1-4 represent cheeses in clusters 1-4. Samples that are located close to each other on the map are likely to carry similar flavor properties. Samples that are located to some attributes are more likely higher in the intensity of those attributes. Attributes that are pointed in the same direction are likely correlated. Conclusions that are drawn from the map should be confirmed by inspecting the raw data.

1.1.2 Consumer Studies

Opinions of actual consumers of a product may be studied using different approaches, generally known as consumer studies. Consumer studies, in combination with descriptive analysis data, provide a better understanding of a product category than only one of these methods could provide. Consumer tests are carried out for product maintenance, product improvement or optimization, development of new products, product category review, or finding support for advertising claims (Meilgaard et al. 2007). More specifically in food manufacturing, product maintenance is understood as situations where already existing products need to be changed in some way due to a change in suppliers, need to reduce costs through change in ingredients, or improve packaging materials. Product improvement or optimization is carried out to improve overall satisfaction with the product; the intensity of key attributes may be decreased, increased, or modified. During the new product development process, affective tests may be needed at several points – in the beginning to test the ideas and throughout the development and marketing to determine whether the product is equal or better compared to competition. Product category review studies may be undertaken to understand the location of the company's product in the marketplace, but also whether there are unmet needs in a specified product category and which key attributes are important in that category. And finally, evidence or support for advertising claims should be acquired through consumer testing, where subjects use the products in question in a balanced test design in a controlled test situation.

Qualitative or quantitative information may be collected during consumer studies (Lawless and Heymann, 1999). Qualitative information from focus group discussions or one-on-one interviews helps in product understanding and also provides information for quantitative research input. Focus groups usually involve about 10 consumers, who are interviewed by a trained moderator. It is necessary for the moderator to control the situation in a suitable manner so as not to lead the participants too much, but still to direct them to find answers to raised questions. One-on-one interviews, as the name refers, require an interviewer and an interviewee; in this approach the interviewer talks to several consumers in a similar format.

In quantitative research it is possible to distinguish preference testing and measurement of magnitude of liking (Lawless and Heymann, 1999). In preference testing the consumer is presented a number of products and asked which product(s) are preferred or even to rank the products in order of preference. Another approach is to use the hedonic scale in liking measurement, for example the 9-point hedonic scale (Jones et al. 1955). The consumers may also rate intensity for certain product attributes, and have a chance to express their personal opinion towards the product samples.

Consumer studies may be carried out in a laboratory, Central Location Trials (CLT) or Home Use Tests (HUT). In a laboratory the test situation is carefully controlled by the tester; however, this situation may not be best suited for the consumer, as this is not the normal circumstances for consumption or using a product (Meilgaard et al. 2007). In the case of a CLT the consumers are invited into a testing facility, where the testing is carried out. Products are prepared beforehand and served on uniform vessels, without their original packaging, coded with three-digit numbers. In this manner several products may be tested, but the testing conditions are still not natural. In the case of a HUT the consumers are provided with samples that they can study in their homes and provide feedback when necessary. This is the most convenient for the consumer, as nowadays feedback can be given through websites or email; however, for the tester this situation cannot be controlled for any influencing factors. HUT tests usually require more time and more consumers; however, more information about the product, possible usage, and packaging might be obtained.

As consumer tests usually carry high variability caused by individual differences in liking, approximately 100 or more consumers are considered necessary for most testings. A high number of subjects provide an opportunity to segment or group the consumers according to their most liked product(s). Depending on the nature of the samples studied some prior consumer segmentation or pre-screening may be necessary to obtain a vision of the actual product users. The key issues to be asked here are consumption habits, age, gender, marital status, income, geographic location, education, etc. As with any studies using human subjects, the participants must be treated according to the Nuremberg Code of Ethics in Medical Research (United States vs. Karl Brandt et al. 1949) and the declaration of Helsinki (Morris, 1966).

1.1.3 Cross-Cultural Studies

Global companies often try to provide uniform products everywhere. At the same time European countries are trying to find and emphasize the uniqueness of locally manufactured and traditional products. Both of these trends are important and are subjected to studies that cover more than one country or products manufactured in several countries. Cross-cultural studies of food products are laborious to carry out. The results however are valuable.

There are a number of cross-cultural studies in scientific literature that have used sensory analysis methods in their research. However international companies have probably carried out such studies for a long time. Some of the recently published cross-cultural studies have shown that variation in cultural background results in different levels of association with different flavor combinations and the acceptance of these. For example, green teas, the consumption of which is considered healthy and growing in popularity, were studied for acceptance in Thailand, USA, and Korea (Lee et al. 2010). While different flavors were preferred in different countries, bitterness was commonly disliked everywhere. The findings of a consumer satisfaction survey of dry-cured ham in five European countries: Belgium, Germany, Denmark, Poland, and Greece (Resano et al. 2011) confirmed Moskowitz et al. (2006) statements on the importance of flavor acceptance over other qualities of food. This was also confirmed by Causse et al. (2010), who studied important attributes and acceptance of fresh tomato varieties in the Netherlands, France, and Italy. However, in this study the authors stressed also the importance of appearance of tomatoes.

It may be difficult to find links between products manufactured in a country and local consumer preferences. Séménou et al. (2007) studied preferences for cold smoked salmon in six European countries and found that locally produced goods may not be always liked best, even though they are familiar in their flavor and composition. There also are products for which significant variations in consumer segmentation may not exist, as was concluded by Januszewska and Viaene (2001) from a study of chocolate in Poland and Belgium.

1.2 Product Categories

A product category study, also known as category review or category appraisal, provides understanding within a group of foods that can be considered as product class or type. For example product categories include, bread, biscuits, tissues, soaps etc. The categories used in the approach can coincide with Codex Alimentarius (www.codexalimentarius.net) official standards or regional legislation; however, in most cases the category is narrowed down based on current needs. Product category studies may be composed of consumer, descriptive, and/or instrumental studies.

In order to fully characterize the whole product category, the sensory language should be developed. According to Drake and Civille (2002) "a lexicon is like a specific technical dictionary that provides a source list to describe a category of products". The lexicon development process should start with collecting as many samples from the category as possible, then generate the descriptive terms according to the sample set, review references and examples available, and develop a final descriptor list (Drake and Civille, 2002). Table 1 lists some of the sensory language development studies for cheese and pomegranate juice.

Table 1. Selection of sensory languages available for cheese, pomegranate juice, and strawberry jams.

Number	Product	Reference
1	Cheese	Heisserer and Chambers (1993)
2	French cheese	Rètiveau et al. (2005)
3	Western European cheese	Talavera-Bianchi and Chambers (2008)
4	Ewe milk cheese	Barcenas et al. (1999)
5	Cheddar cheese	Drake et al. (2001)
6	Imitation cheese	Drake et al. (2010)
7	Pomegranate juice	Koppel and Chambers (2010)
8	Strawberry jam	Bursac et al. 2007, Koppel et al. 2011

For some products, flavor or aroma wheels have been developed. These provide experts the possibility to characterize products using certain words for certain properties and can be used in product quality control purposes as well. Examples include virgin olive oil flavor wheel (Mojet and de Jong, 1996), cheese flavor wheel (Appelbye et al. 1994), and the wine aroma wheel (Noble et al. 1987), etc.

1.2.1 Pomegranate Juice

According to Codex Alimentarius General Standard for Fruit Juices and Nectars, a fruit juice is the unfermented, but fermentable liquid obtained from the edible part of sound, appropriately mature and fresh fruit or of fruit maintained in sound condition by suitable means including post harvest surface treatments applied in accordance with the applicable provisions of the Codex Alimentarius Commission (Codex Stan 247). The pomegranate juice category involves juices manufactured from pomegranates (*Punica granatum L.*) by mechanical extraction processes, fruit juice from concentrate is concentrated fruit juice reconstituted with potable water, concentrated fruit juice, where water has been physically removed, or water extracted fruit juice, which is obtained by diffusion with water of dehydrated whole fruits.

The sensory properties of pomegranate juices have not been extensively studied although the considerable health benefits that the juices carry have lead to increased consumption. For example, a review by Viuda-Martos et al. (2010) captures studies on functional properties of pomegranates such as anti-inflammatory, antitumoral, antimicrobial, antioxidant, and antidiabetic properties, effect on cardiovascular, skin, and oral cavity health. Seeram et al. (2008) compared pomegranate juice total phenolics and antioxidant potency against 11 other drinks considered rich in antioxidants. Within that study pomegranate juice had higher content in total phenolics and also higher antioxidant potency compared to wine, fruit juices, and different teas.

Data showing differences in chemical composition among pomegranate cultivars suggests variation in flavor properties. The sugar content varies from 11-13 g/100g in sour, sour-sweet, and sweet cultivars in Turkey (Ozgen et al. 2008) and in Spain (Melgarejo et al. 2000). The acid content varies from 0.3 in sweet cultivars to 0.8-1.9 in sour-sweet and up to 2.7 g/100g in sour cultivars. The difference between sweet, sour-sweet, and sour cultivars sweetness intensity is not caused by variations in total sugar content, but in total acid content. The organic acids present in pomegranates are citric, malic, oxalic, acetic, fumaric, tartaric, and lactic acid, while the two main sugars are glucose and fructose (Melgarejo et al. 2000).

Some studies have used restricted sensory analysis among other methods in evaluation of quality of pomegranates or pomegranate juices. Some of the examples include Martinez et al. (2006), who described five new pomegranate varieties using attributes like seed hardness, visual color, taste, and overall quality appreciation. The aroma, taste, firmness, visual appearance, color, browning, and dehydration of pomegranates were evaluated by Lopez-Rubira et al. (2005) when studying the shelf life of pomegranate arils. Vardin and Fenercioglu (2003) studied the clarification of pomegranate juices and evaluated attributes like color, turbidity, overall appearance, bitterness, and overall quality. Melgarejo et al. (2011) and Calin-Sanchez et al. (2011) studied the aroma of fresh pomegranate juices prepared from Spanish cultivars. They concluded that pomegranates are low in odor intensity, thus flavor is more important for consumers, characterized mainly by sweetness and astringency. None of the studies included a detailed lexicon for the classification of the flavor attributes of pomegranate juice, or compared products by countries or by product types.

Consumer satisfaction has been studied with pure pomegranate juices and pomegranate juice mixtures with other juices. Riaz and Elahi (1992) studied carbonated pomegranate drinks. Relatively low levels of 10-20% pomegranate juice were liked best. The liking of mixed fresh juices was also studied by Endrizzi et al. (2009). Pomegranate, pineapple, apple, orange, and blood orange juices were mixed with strawberry, raspberry, blackberry, red currant, and blueberry juices. The consumers disliked mixtures with pomegranate juice and liked pineapple and blood orange mixes best. Vázquez-Araújo et al. (2010) studied consumer liking of pomegranate juice mixed with other juices and found juice mixtures which contained 90% pomegranate and 10% blackberry or raspberry juice were highly liked. However, all of the juices were mixtures with pomegranate juice, so there was no possibility for the consumer to choose a juice that did not contain any pomegranate juice. Fresh pomegranate juice acceptance was studied small-scale by Melgarejo et al. (2011) and Calin-Sanchez et al. (2011) in Spain. Consumers evaluated liking towards nine juices prepared from different cultivars. It was concluded that consumers mainly like the sweetness of the juices and, thus, like juices that were prepared from cultivars that produce lower amounts of organic acids better. According to these studies there is considerable variation among consumer opinions towards pomegranate juices and mixtures of juices.

1.2.2 Strawberry Jam

Strawberry is used extensively as an ingredient or as added flavoring in foods. Sensory quality of processed strawberries depends on the formulation, pretreatment of the fruit, and also the properties of the cultivar used. The Codex Alimentarius Standard for Jams, Jellies, and Marmalades (Codex Stan 296) requires at least 35% of fruit in the finished product. This does not apply for dietary or otherwise specialty products though. There are no requirements for strawberry jam sensory properties. Studies by Bursac et al. (2007) have characterized the sensory properties of strawberry jams to determine whether cultivar influences the properties of strawberry jams. It was found that the cultivars can be associated with different sensory properties in fruits, jams, and purees. King et al. (2006) reported that sucrose or carbohydrates may accent strawberry flavor, thus the amount of sweetening agents used can be associated with the final flavor intensities.

Strawberry jams often differ in the amount of whole fruits present in the final product. Pretreatment of strawberries as suggested by Suutarinen et al. (2000,

2002) proved to help in manufacturing jams with whole berries, which may be a desirable trait from a consumer point of view.

The knowledge of different cultivars and technology effect on flavor and texture of strawberry jams are only valuable if consumer opinions of preferred products are available. Consumer studies have shown that consumers prefer sweeter jams and least accept low-calorie products and products with low sweet taste intensities. Consumers also prefer strawberry jams that are lighter in color and red (Alves et al. 2008).

So far no studies had been conducted on sensory evaluation of a category of commercial strawberry preparations, with the aim to characterize the sensory profiles of the product clusters or to map flavor differences by country of manufacture. Also, there was no research found on chemical or physical properties of commercial strawberry preparations.

1.2.3 Cheese

According to Codex Alimentarius General Standard for Cheese, cheese is the ripened or unripened soft, semi-hard, hard, or extra-hard product, which may be coated, and in which the whey protein/casein ratio does not exceed that of milk, obtained by:

- Coagulating wholly or partly the protein of milk, skimmed milk, partly skimmed milk, cream, whey cream or buttermilk or any combination of these materials through the action of rennet or other suitable coagulating agents /…/ (Codex Stan 283).

The main components of cheese are milk protein and fat. Cheese flavor formation is a complex process which is closely related to degradation of milk caseins and fat and fermentation of milk sugars (McSweeney and Sousa, 2000). Milk proteins are hydrolyzed into peptides and amino acids by chymosin, milk plasmin, microbial proteinases and peptidases. Milk fat triglycerides are subjected to lipolysis by lipases; this results in free fatty acids. Lactose during cheese ripening is quickly converted to lactate. The major sourness of cheese is the result of fermentation of lactose into lactate by lactic acid bacteria (LAB) introduced by the starter culture. Depending on the milk source dairy notes are likely to be present in cheese flavor, and flavor compounds responsible for barnyard-related or animal-related properties may exist (Heisserer and Chambers 1993). Cheese technology and maturation conditions like surface ripening or coating influence flavor characteristics. Salt in cheese not only enhances the other flavors, but also acts as an inhibiting agent against bacterial growth (Walstra et al. 2006). Depending on the level of maturation, cheese may contain several different volatiles which result in a specific flavor. These volatiles may be amines, sulphur compounds, aldehydes, alcohols and their esters, fatty acids and lactones. Some of these compounds may also be responsible for off-flavors in cheese (Walstra et al. 2006).

The sensory properties that result from the biochemical processes of cheeses have been characterized from around the world, including those from specific regions or specific types. In Europe cheese made from Italian ewe's milk was studied by Scintu et al. (2010), a Norwegian cheese variety "Norvegia cheese" was evaluated by Hersleth et al. (2005), French Comte cheeses were described by Berodier et al. (1997) and Monnet et al. (2000); European Emmental cheeses were studied by Pillonel et al. (2002) and Karoui et al. (2006); and French raw and pasteurized cheeses were compared by Chambers et al. (2010). Ritvanen et al. (2005) described the texture and flavor as well as consumer acceptance of full fat and reduced fat Havarti, Edam, and Emmental cheeses in Finland. In South America Sihufe et al. (2010) studied the properties of an Argentinean cheese. Drake et al. (2009), Caspia et al. (2006) and Young et al. (2004) have studied various Cheddar cheeses flavor and preferences in the US.

Studies with an objective of composing a cheese flavor lexicon have used data that was collected from several different countries. Heisserer and Chambers (1993) developed a lexicon according to attributes present in 42 aged natural cheeses from 13 countries. A lexicon for French cheeses was composed by Rètiveau et al. (2005). The attributes were divided into seven flavor categories, including fundamental tastes, dairy aromatics, fatty acid/animal, musty/fungal, aged/fermented, and other aromatics and mouthfeelings. A wide range of Western-European cheeses varying in country of origin, fat content and milk types, were studied by Talavera-Bianchi and Chambers (2008) with the incentive to limit the existing lexicons to fewer sensory attributes. A lexicon specific to US Cheddar cheese was developed by Drake et al. (2001), who found that the majority of the attributes were present in most of the cheeses, varying only in intensity.

Official standards of cheese are not highly specific about flavor. For example, the Codex Alimentarius Standard for Tilsiter (Codex Stan 270) does not characterize the required flavor properties, while the standard for Emmental cheese (Codex Stan 269) notes that the typical flavor is mild, nut-like, and sweet; thus there is room for further flavor characterization of cheese. Similarly it can be important to understand flavor development and flavor characteristics of foods from a certain region, as more products are designated as local or regional specialties. In addition, developing a wider perspective of the flavor characteristics of foods available in different continents, e.g., the flavor of cheese and how it is a combination of cultural, geographic and historic factors is important. No information was found on Estonian cheese flavors and liking. There is also little information on any kind of cross-cultural studies with cheese concerning variation of descriptive characteristics in cheeses from different countries.

AIMS OF THE STUDY

The aim of the present study was to appraise the methods and the product categories through case studies with pomegranate juices, cheeses, and strawberry jams by carrying out the following:

1) develop and apply a lexicon to describe flavor properties and compare flavor and aroma of pomegranate juices (Paper I, II),
2) compare flavor and composition properties of strawberry jams and flavors of cheeses manufactured in Europe (Paper III, IV, V),
3) compare acceptance of cheeses within Estonia and acceptance of pomegranate juices between Estonia, Spain, Thailand, and US (Paper IV, VI).

MATERIALS AND METHODS

2.1 Materials

2.1.1 Pomegranate Juice

Commercially available pomegranate juice samples were studied (Paper I, II, VI). The juices were obtained from the US, Estonia, Spain, and Thailand (Table 2a-b). The samples included juices that were direct extract, concentrated, were made from concentrate, contained natural flavors, or were freshly squeezed. The juice concentrates samples were diluted with purified water before evaluation. The products were obtained 3–4 weeks before testing and were stored according to the recommendations given on the packages. The samples were evaluated before "best before" date. All samples were thermally treated by the manufacturers except for the fresh-squeezed juice (Paper II), which was pressed from Wonderful variety pomegranates.

Table 2a. List of pomegranate products names, abbreviations, and country of origin or packaging (Paper I, II, VI).

Abbr	Product Name	Comments	Country
Juice	4U pomegranate Juice	Pomegranate juice of first directly pressing	Azerbaijan
Fconc **	L&A All Pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	USA
Juice	100% Pomegranate Juice	Pomegranate juice	Azerbaijan
Juice	Aveesa Pomegranate Juice	Fresh pressed pomegranate juice from whole ripe pomegranates. Potassium sorbate is added as preservative.	Azerbaijan
Conc **	Jarrow Pomegranate Juice Concentrate	Pomegranate Juice Concentrate, 1:4	USA
Conc **	Puritan's Pride Pomegranate Concentrate	Pomegranate concentrate, purified water, potassium benzoate, potassium sorbate, 1:1	USA
Fconc	Pomegranate Juice Ziyad	Water, 100% pomegranate concentrate	Turkey
Juice **	Lakewood organic pure pomegranate fresh pressed 100% juice	Fresh pressed juice from whole ripe certified pomegranates	USA
Fconc	AC Fresh 100% Pomegranate Juice	100 % Pomegranate juice from concentrate	Thailand
Fconc, B	RW Knudsen family Just Pomegranate 100% premium pomegranate juice from concentrate	Pomegranate juice, filtered water (sufficient to reconstitute), pomegranate juice concentrate	USA
Fconc **	Langers Pure 100% All Pomegranate juice	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	USA
Fconc	Pomegranate concentrate by Culinary Traditions	Pomegranate juice concentrate, filtered water, 1:1.5	USA
Fconc	Heirloom Farms 100% Pomegranate Juice	Pomegranate juice (pomegranate juice concentrate, filtered water), natural flavor	Turkey
Juice	Elite Naturel: 100% organic natural pomegranate juice	100% Organic pomegranate juice	Turkey
Fconc	Northland 100% Pomegranate Juice Pure Pomegranate	100% Pomegranate juice (filtered water sufficient to reconstitute pomegranate juice concentrate), natural flavors, vegetable color	USA
Conc	Tree of Life Pomegranate Concentrate	Pomegranate concentrate, 1:5	USA
Fconc **	Earthly Delights pomegranate juice from concentrate	Pomegranate juice concentrate, natural flavors, grape seed extract	USA
Conc	Lakewood Pure Pomegranate Concentrate	Pomegranate Juice Concentrate, Vitamin C (ascorbic acid), 1:1.6	USA

**Sample used in Paper II; Juice – squeezed from pomegranates; Fconc – juice from concentrate; Conc – concentrated juice; Abbr – sample abbreviations, used in Fig. 3.

Table 2b. List of pomegranate products names, abbreviations, and country of origin or packaging (Paper I, II, VI).

Abbr	Product Name	Comments	Country
Fconc	Dimes 100% Pomegranate Juice	100 % Juice from concentrated pomegranate juice (water 77,08%)	Thailand
Conc	Woodstock Farms Juice Concentrate Pomegranate	Pomegranate juice concentrate, 1:3	USA
Conc **	Life Extension Pomegranate Juice Concentrate	Pomegranate juice concentrate, purified water, 1:1	USA
Juice	Brighty Pomegranate Juice	Pomegranate 85%, fructose 15%	Thailand
Juice	Elite Naturel	100% Pomegranate juice	Turkey
Conc **	RW Knudsen Pomegranate Juice Concentrate	Pomegranate juice concentrate, 1:3	USA
Fconc **	POM Wonderful	Pomegranate juices from concentrate and natural flavors	USA
Juice C	Granavida pomegranate juice 100% natural	100% Elche pomegranate extract, direct extract	Spain
Fconc **	Swanson Pomegranate Juice	Reconstituted pomegranate fruit concentrates, purified water, potassium benzoate and potassium sorbate	USA
Fconc D	Old Orchard Premium Pomegranate Juice	Pomegranate Juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors, ascorbic acid (vitamin C), vitamin E acetate	USA
Fconc	Archer Farms Pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavor.	USA
Fconc	Indo-European Pomegranate Juice	Pure pomegranate juice and pomegranate concentrated blend	USA
Fconc **	Whole Foods 365 100% Juice Pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavor	USA
Juice **	Hyson Pomegranate Juice	Fresh squeezed pomegranate juice, potassium sorbate	Turkey
Conc **E	Dynamic Health Pomegranate Concentrate	Pomegranate juice concentrate, 1:3	USA
A	100% Pomegranate juice	Pomegranate juice concentrate, water	Azerbaijan
B1*	Langers Pomegranate Juice Cocktail from Concentrate	Filtered water, sugar, pomegranate juice concentrate, natural flavors and citric acid	USA
F**	Fresh squeezed juice from Wonderful Cultivar	Pomegranate juice	USA

*Sample was purchased in Thailand and used only in the CLT in Thailand; **Sample used in Paper II; Juice – squeezed from pomegranates; Fconc – juice from concentrate; Conc – concentrated juice; Abbr – sample abbreviations, used in Fig. 3.

2.1.2 Strawberry Jam

Twenty-five strawberry jams (Table 1, Paper III) were studied. All of the samples were coded by country and a number. The samples were acquired up to 1 month before analysis and stored according to the instructions given on the package. All samples were purchased from supermarkets in Tallinn, Estonia and were of Estonian (n = 5), Finnish (n = 2), Danish (n = 6), Norwegian (n = 1), Swedish (n = 1), Spanish (n = 2), German (n = 3), Greek (n = 1), French (n = 2), Lithuanian (n = 1) and Hungarian (n = 1) origin. Except for sample Est5, that was stored refrigerated (6–10˚C), the samples were stored at room temperature. The samples included specialty jams that were either manufactured without added carbohydrates, with fructose, with artificial sweeteners, or organic. The samples contained 35–102 g of berries per 100 g product and 0–65 g carbohydrates per 100 g of product. Sample Fin1 was excluded from sensory and instrumental results means in cluster 2.

2.1.3 Cheese

The Estonian cheese samples (n=36, Table 3) from eight different local cheese manufacturers were manufactured from cow's milk (Paper IV). All of the samples were available in 2009 and 2010 in grocery stores in Tallinn, Estonia. The samples were purchased and stored refrigerated. For descriptive sensory analysis the samples were shipped to the Sensory Analysis Center, Manhattan, KS, USA within a week from purchasing. The samples were stored at 2-6 °C and analyzed within a month from receipt; always before the "best before"-date. Four samples were chosen for the consumer acceptance study.

2.1.3.1 Cheese Flavor from Different Countries

Sample cheeses (n=152, Table 1 in Paper V) for the cross-countries cheese study were purchased and analyzed as described by research by Retiveau et al. (2005), Talavera-Bianchi and Chambers (2008), Chambers et al. (2010), and Paper IV. Retiveau et al. (2005) purchased the 43 samples varying in maturation time, milk source, region, and processing method; the samples were manufactured in France. Talavera-Bianchi and Chambers (2008) purchased 65 European cheeses varying in fat content, country of manufacture, and milk source in Germany. Chambers et al. (2010) described seven types of cheeses which were manufactured in France either from raw or pasteurized milk. Paper IV samples were purchased from Estonia. The samples varied in maturation time, fat content, and manufacturer. The samples were coded according to the manufacturing country (first letter/letters: US – U, Italy – I, Spain – Sp, Estonia

– Es, England – E, Switzerland – S, Austria – A, Ireland - Ir, Greece – Gr, Germany – G, Denmark – D, Holland – H, France – F, Sweden – Sw, Norway – N, Belgium - B) and consecutive numbers.

Table 3. Estonian cheese sample codes, names, producers or packagers, and fat contents (Paper IV).

Code	Sample Name	Producer/ packager	Fat %**
107	Valio Gouda Black Label	Valio	29
150*	Saare Leet Juust	Saaremaa	24
168	Naeru Juust	Piimandusühistu E-Piim	24
173	Valio Võru Juust Edam	Valio	27
198	Bret Blue	Luke Framimeierei OÜ	15-30
201*	Põltsamaa Eesti Juust	Piimandusühistu E-Piim	26
208	Kostroma Juust	Saaremaa	26
211	Eesti Juust Light	Estover	18.4
295	Südamejuust	Piimandusühistu E-Piim	26
297	Dr Hellus juust	Tere	26
300	Hiirte Juust	Estover	25
327	Köömne juust	Maag	25
344	Atleet	Valio	26
348	Eesti Juust Originaal	Estover	25
349	Hea Juust	Estover	22
381	Eesti Juust	Estover	26
408*	Valio Gouda Red Label	Valio	29
411	Saare Light Juust	Saaremaa	15
431	Kadaka juust	Saaremaa	26
434	Valio Võru Juust Havarti	Valio	30
516*	Saaremaa Ekstra Juust	Saaremaa	26
580	Edam	Piimandusühistu E-Piim	24
606	Eesti Kuldne Juust	Piimandusühistu E-Piim	N/A
607	Hollandi Juust	Piimandusühistu E-Piim	N/A
628	Atleet Light	Valio	19
712	Hollandi Leibjuust	OÜ Põltsamaa Meierei	25
769	Alma Eesti Juust	Valio	27
772	Oma Juust	Estover	22
776	Lepasuitsu Eesti Juust	Piimandusühistu E-Piim	26
819	Saaremaa Edam Juust	Saaremaa	24
836	P6ltsamaa Eesti Light Juust	Piimandusühistu E-Piim	15
845	Estman	Piimandusühistu E-Piim	26
873	Hollandi Leibjuust	Saaremaa	26
911	Mirjami juust	Piimandusühistu E-Piim	24
912	Vene Juust	Estover	25
932	Pühajärve Juust	Estover	28.5

*Samples used in the consumer study in Estonia; ** Fat content as shown on the labelling; N/A – not available

2.2 Descriptive Sensory Methods

Descriptive sensory analysis was carried out in the Sensory Analysis Center, Kansas State University, Manhattan, KS, US (Paper I, II, IV, VI), and in the Competence Center of Food and Fermentation Technologies, Tallinn, Estonia (Paper III). Two methods were used: a modified flavor profile approach (consensus, Paper I, II, VI), and descriptive analysis (individual scores, Paper III, IV) depending on project needs and objectives.

2.2.1 Modified Flavor Profile Approach

A method adapted from the flavor profile method (Caul, 1957; Keane, 1992) was used. The original method uses a scale of 0 - 3 points with a possibility to add 0.5 increments. In addition, the original method usually includes analysis of flavor, aroma, overall impression, and aftertaste. Our adaptation from the original method in Papers I, II, and VI uses a scale with 0.5 increments where 0 represents 'none' and 15 'extremely strong' for intensity measurement. Each sample was evaluated for the flavor attributes that were present in the sample and each panelist individually assigned intensities to the attributes according to the flavor references included in the lexicon. All of the recorded attributes and their intensities were discussed by the panel. In cases where a new attribute emerged, a discussion between the panel leader and the panelists, using the consensus approach, would focus on the appropriateness, definition, references, and evaluation technique of that attribute. A similar approach has been previously used by Talavera and Chambers (2008), Retiveau et al. (2005), and others.

2.2.2 Descriptive Sensory Analysis

Descriptive analysis by trained panelists was used in Paper III and IV. The attributes, definitions and reference materials were agreed upon before testing, when the panelists had access to all the samples to be tested. The experiment was run in three repetitions. A scale with 0.5 point increments, where 0 = none and 15 = very strong, was used. Unsalted crackers and purified filtered water was available for palate cleansing at all times, as well as reference materials and definition sheets.

2.2.3 Panelists

Trained panelists from the Sensory Analysis Center, Kansas State University (external panel, n=5, Paper I, VI and n=6, Paper IV) and Competence Center of Food and Fermentation Technologies (internal panel, employees of the Center, n=8, Paper III) participated in the studies. All of these panelists had completed general descriptive analysis panel training with a variety of food products. For these studies the panelists also received further orientation on the product to be tested.

2.3 Consumer Studies

The Central Location Trials (CLT) were carried out in the Competence Center of Food and Fermentation Technologies, Tallinn, Estonia (Paper IV, VI), in The Sensory Analysis Center, Kansas State University, Manhattan, KS, US (Paper VI), Departamento de Tecnología Agroalimentaria, Grupo Calidad y Seguridad Alimentaria, Universidad Miguel Hernández, Alicante, Spain (Paper VI), and Kasetsart University, Sensory and Consumer Research Center, Bangkok, Thailand (Paper VI).

2.3.1 Cheese Acceptance

For the consumer study four samples (150, 201, 408, and 516, Table 3) were chosen (Paper IV). Sample 381 was used as a warm-up sample to reduce the first sample bias often noted in consumer studies, and results for this sample were not used in data analysis. The samples were purchased from grocery stores in Tallinn in August 2010, and the study was carried out in September 2010 in Tallinn, Estonia. The cheeses were cut into 1.2 cm cubes and placed into covered 40 ml disposable plastic cups, labeled with three-digit codes. The samples were served at room temperature.

One hundred eleven adult consumers (33 men and 78 women), who identified themselves as cheese consumers, were recruited via e-mail and fliers in Tallinn, Estonia. The consumers tasted the cheeses in a single session. A break of 2-3 min was provided between samples, and consumers were encouraged to take a bite of unsalted cracker and drink the purified water that was provided during these breaks. The cheeses were presented individually in a randomized order. The ballot for each cheese included questions on cheese liking (overall liking, flavor liking, dairy flavor liking, sweet, sour, and bitter taste liking) on a 9-point hedonic scale, where 1 = dislike extremely and 9 = like extremely. The consumers were also asked about the intensity of these attributes on a 5-point just-about-right (JAR) scale where 1 = extremely weak, 3 = just about right, and 5 = extremely strong.

2.3.2 Pomegranate Juice Acceptance

Consumer acceptances were studied in Estonia, US, Spain, and Thailand. The studies took place in December 2010 in US and Estonia, in January 2011 in Spain, and in February 2011 in Thailand (Paper VI). Approximately one hundred consumers, with a ratio of 60:40 women and men, respectively, were recruited in each country for a central location test.

All of the participating consumers were recruited via e-mails and fliers in all participating countries. The consumers had to fill in a screener to state their gender, age, and diet restrictions or allergies. The consumers were asked about juice consumption frequency and willingness to taste pomegranate juice from a selection of juices. Consumers, who stated they were 18-64 years old, drank any kind of juice at least two times per week, had no diet restrictions or allergies, and were willing to taste pomegranate juice, were recruited for testing.

The ballots, screeners, and demographic questionnaires were translated from English to Estonian, Spanish, and Thai and then back to English to confirm no major misinterpretations took place during the translation process.

From the day before testing the samples were cooled and stored in a refrigerator (3-5 °C, Table 2a-b). The samples were poured into disposable plastic cups approximately 1-1.5 hours before testing, and just before serving were stirred using a plastic disposable spoon. The samples were served (appr. at 5-7 °C) in a randomized order. The consumers were suggested to clean the palate with purified water and unsalted crackers after tasting a sample. The consumers were asked to answer questions on a 9-point liking scale where 1 = dislike extremely and 9 = like extremely about overall, flavor, sweet taste, sour taste, fruity flavor, pomegranate flavor, and aftertaste liking. The consumers were also asked about flavor, sweetness, sourness, fruitiness, pomegranate flavor, and aftertaste intensities on a 9-point JAR scale where 1 = extremely weak, 5 = just about right, and 9 = extremely strong.

The last question for each sample was a check-all-that-apply (CATA) question. The consumers were asked to read through all of the choices that concerned the appearance or mouthfeel of the juice (pulpy, smooth, mouthpuckering/astringent), different flavor attributes (floral, wine-like flavor, fruity like a grape, fruity like a raisin, fruity like cranberry, fruity like a cherry, candy-like flavor, pleasant flavor, fruity like a berry, musty like a beet, fermented flavor), attitudes toward the juice tasted (nasty flavor, for adults, for kids, for the entire family, fruit juice with other added ingredients, 100% fruit juice, fruit-flavored drink, I would consider buying this, I would drink every day, I would drink occasionally, I would drink at any time, I would drink when I want a snack, I would drink with meals, I have no interest in buying this, I would drink on special occasions, I would drink when I am thirsty, cheap, expensive, high in sugar, low in sugar, natural color, artificial color, familiar flavor, unfamiliar flavor, natural taste, artificial taste, healthy, unhealthy) and check the ones that applied for that sample.

After tasting all samples the consumers were asked to fill in a demographic screener and answer questions on their gender, age, education level, and juice consumption habits.

2.4 Chemical-physical Methods

2.4.1 Brix, PH, Color, and Hardness

All measurements were carried out in triplicate and the results were averaged (Paper III). The dry weight of the samples was measured with a Mettler Toledo HR83Moisture Halogen Analyser (Mettler Toledo, Columbus, OH, US) and the Brix using a refractometer, PAL-1 (Atago, Japan), calibrated against distilled water.

Surface color was analyzed using a spectrophotometer CM-600d (Konica Minolta, Japan), calibrated with a white tile; the pH and acidity was measured using a Mettler Toledo DL20 Compact Titrator. For pH and titratable acidity measurements, the sample (5 g) was diluted with distilled water (50 g) and homogenized with a homogenizer (Polytron PT 2100, Kinematica, Lucerne, Switzerland) at speed of 11,000 rpm.

Rheological analysis was carried out with a Texture Analyzer, T.A.XT. Plus (Stable Microsystems, U.K.) using a 40 mm diameter cylinder probe. The samples were compressed with speed 1.0 mm/s and the load cell with 5 kg. Hardness of the sample was measured as force (g) that was required to penetrate 15 mm into the sample.

2.4.2 Sugars and Acids Contents

The concentrations of sugars (maltotriose, disaccharides, glucose and fructose) and organic acids (malic acid and citric acid) in the strawberry jams were analyzed by high-pressure liquid chromatography (Alliance; Waters Corp., Milford, MA, US) using a Bio-Rad HPX-87H column (Hercules, CA, US) and isocratic elution at a flow rate of 0.6 mL/min with 0.005 M H_2SO_4 at temperature 35 °C (Paper III). A refractive index detector (model 2414; Waters Corp.) and dual l absorbance detector (model 2487; Waters Corp.) were used for detection and quantification of the sugars and acids. The samples of jams (1 g) and distilled water were homogenized (11000 rpm, 4 min), centrifuged (3500 rpm, 10 min) and supernatant was diluted (10x) in elution. Data processing was performed using Empower software (Waters Corp.).

2.4.3 Analysis of Volatile Composition

The volatile aroma compounds were extracted (Paper II). The isolation, identification and semiquantification of the volatile compounds were performed on a gas chromatograph (Varian GC CP3800; Varian, Walnut Creek, CA, US) coupled with a Varian mass spectrometer (Saturn 2200) and operated with MS Workstation software. Most of the compounds were identified using two different analytical methods: (a) Kovats indices; (b) mass spectra (authentic chemicals and Wiley spectral library collection). To semiquantify the volatile compounds, 1,2-dimethoxybenzene was used as internal standard (final concentration in the sample of 4 mg/kg).

2.5 Data analysis

Mapping of samples as biplots according to mean scores was carried out in Paper I, III, IV, and V using Principal Component Analysis (PCA). In PCA biplots the sample scores and variable loadings are visualized on the same map. Partial Least Squares Regression (PLSR) was used in Paper II to map connections between instrumental aroma measurements and sensory analysis data.

The data analysis included clustering of samples or consumers using K-means (Paper III, V, and VI), AHC (Paper IV), or the CLUSTER procedure in SAS (Paper I). The method selection was dependent on the outcome, mainly the possibility to explain the results based on clustering. For consumer data cluster number was selected as two due to limitations by the overall number of consumers in a study. In descriptive studies the number of clusters was selected either automatically or a number based on the visual inspection of data and PCA mapping results. Correlations between attributes were found using Pearson Correlation Coefficient ($p=0.05$).

One-way analysis of variance (ANOVA) was used to detect statistically significant ($p<0.05$) differences between samples (Paper III, IV, VI) and differences between consumer clusters (Paper IV, VI).

The Statistical Analysis System (SAS, Cary, NC, US), XL Stat (AddInSoft, New York, NY, US), and Unscrambler (Camo Software, Norway) were used in data analysis.

RESULTS AND DISCUSSION

3.1 Characterization of Flavor

3.1.1 Pomegranate Juice Flavor Lexicon (Paper I)

The lexicon composing of 33 flavors found in pomegranate juices was created in this study (Table 2, Paper I). As the lexicon was composed based on analysis of a large set of juices sold in several countries (Estonia, Spain, Thailand, and mostly in the US), this lexicon contains most of the sensory properties important for pomegranate juices, and may be used for pomegranate juice sensory evaluation anywhere. However, it cannot be excluded that additional flavors exist.

The current study revealed that pomegranate juice is a versatile product category as various flavor combinations were found. Pomegranate juice flavor may be generally described as sour and sweet, with an astringent mouthfeel. In addition the juices often carry some musty/earthy and different fruity aromatics such as grapes, cranberries, but also vegetable notes such as beets or carrots.

Manufacturing technology seems more important in defining the flavors present in pomegranate juices than the origin of raw material. According to Fig. 3 concentrates, juices from concentrate and direct extract juices vary within flavor profiles. Concentrates can mostly be found in the dark-fruity region of the map, most likely caused by thermal treatment of the juices, which results in characteristic flavor. Direct extract juices and juices from concentrate were scattered all over the map, but were mostly found in the fruity and berry section, which may partly be caused by flavorings that were added to some of the juices manufactured from concentrates. In respect to importance of country or origin, most Turkish juices were located together with juices manufactured in Azerbaijan in the fruity region of the map. US sold juices (or juices sold by US companies, disclosing country of origin) covered the whole range of flavor variations. No strict associations were found between a country of origin and flavor composition within pomegranate juices studied. Oupadissakoon et al. (2009) reached a similar conclusion in a study comparing ultra-high-temperature milks manufactured in different countries – differences in flavor profiles may be caused by manufacturing technologies rather than country of origin.

The 33 juices studied were divided into five flavor clusters (Paper I, Table 4). Whether the flavor profiles representative of these clusters would actually be accepted by consumers, was studied further in chapter 3.2.2.

Although a great variation of flavors and flavor intensities was found, there are some main flavors that are important in recognizing a pomegranate juice. These flavors include grape, cranberry, berry, fruity-dark, musty/earthy, and beet. Astringent mouthfeel and sour, sweet, and bitter tastes are usually present in pomegranate juices.

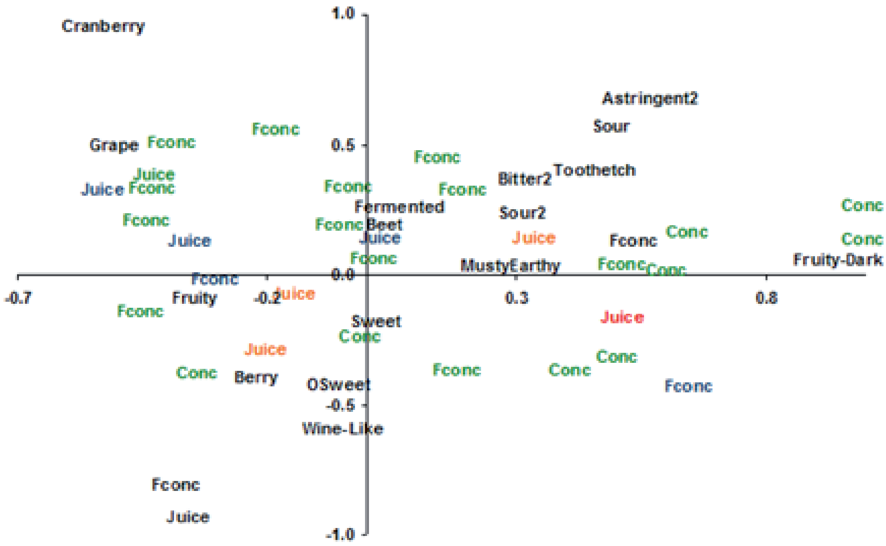

Fig. 3. Principal Components Analysis map of pomegranate juices according to juice type and country. PC1 explains 29% and PC2 18% of the variation within data. Juice – squeezed from pomegranates; Fconc – juice from concentrate; Conc – concentrated juice. Red – juice manufactured/labeled in Spain, green – US, orange – Azerbaijan, blue – Turkey, black – Thailand.

3.1.2 Pomegranate Juice Flavor and Aroma (Paper II)

The pomegranate flavor lexicon created in Paper I was used to compare flavor properties of commercial juices and fresh juice. The commercial samples were divided into direct extracts, juices with added flavorings, juices from concentrate and one concentrated juice. Moderate sweet overall and fruity notes, and low berry, cranberry, floral, fruity-dark and musty/earthy flavors were detected in the fresh juice sample. The direct extract juices had grape and wine-like notes in addition. Most of these flavors were also present in the juices with added flavorings, but not all of them in juices from concentrates. In fact, some processing-related notes, such as molasses, woody, candy-like, and stronger fruity-dark were present in juices made from concentrates.

A Partial Least Squares (PLS) regression analysis between sensory data and instrumental aroma measurements was carried out in order to detect possible relationships. Juice type had an important part in the aroma compounds present in a sample as the main differences between fresh and commercial samples were detected in the terpenes (present in fresh and not dominant in commercial) and furans (present in commercial and absent in fresh), probably because of the pasteurization process applied to the commercial samples. Although the correlations between sensory and instrumental data were not strong, the fresh juices, juices with added flavors, and direct extracts (characterized by fruity notes) were clearly separated from juices from concentrate (fruity-dark notes); furans (for example furfural and 2-furaldehyde) were important in the aroma of commercial samples and terpenes (for example limonene and ß -caryophyllene) and aldehydes (for example hexanal and nonanal) in the fresh squeezed juice. According to these results there are differences between commercial and fresh juice in the sensory profile and in the instrumental aromatic profile. This should be noted in a category evaluation as from the point of view of a consumer similar flavor experience from a processed juice as perceived from a fresh-squeezed juice can be expected. Thus careful aroma recovery during concentration or addition of selected flavorings should be considered by industries, such as partial distillation or pervaporation of the water phase, suggested by Sampaio et al. (2011).

High correlations between instrumental aroma profiles and descriptive sensory profiles were not found. This may be caused by difficulties of separating a flavor from a profile of multiple aromas as well as using real foods as reference materials. In order to achieve higher correlations between flavor and aroma measurements the use of chemical reference material should be considered for the sensory panelists.

3.1.3 Strawberry Jam Flavor Clusters and Connections to Instrumental (Paper III)

The jams studied included ordinary strawberry jams and several specialty jams, such as 100% berries, jams with sweeteners, or organic products. The products were different in color (brown or red), taste and flavor (sour, bitter, astringent, level of strawberry flavor), and texture (thickness and granularity). The jams were divided into three clusters according to their sensory properties (Fig. 4). Cluster 1 - natural, red, sweet, and strawberry-flavored jams; cluster 2 - artificial-flavored, granular-textured jams low in berry content and berry flavor; cluster 3 - brown, sour, astringent, and low in sweetness strawberry jams. The strawberry jam clusters presented were composed of the following samples:

- Cluster 1: Den4, Den6, Est1, Est2, Fin2, Fra1, Ger3, Lit1, Nor1,
- Cluster 2: Den3, Est3, Fin1, Gre1, Hun1, Swe1,
- Cluster 3: Den1, Den2, Den5, Est4, Est5, Fra2, Ger1, Ger2, Spa1, Spa2.

Differences between the clusters instrumental properties prevail in their Brix, dry weight, sucrose, glucose, and total sugars values, according to which cluster 3 exhibited lower values than cluster 1 and 2 (Table 4). These differences may be explained by the high amount of specialty jams in cluster 3. Cluster 3 has a higher mean value for fructose, which is caused by three of the samples (Spa1, Ger 1, Ger2) that contained fructose or fructose syrup in the formulation. Citric acid and also total acid values were lower in cluster 2. Hardness of the samples was highest in cluster 1, which was the cluster more pronounced in whole berries and berries overall attributes. These mean values could give a product developer a starting-point in the basic sensory and instrumental values when developing a new product.

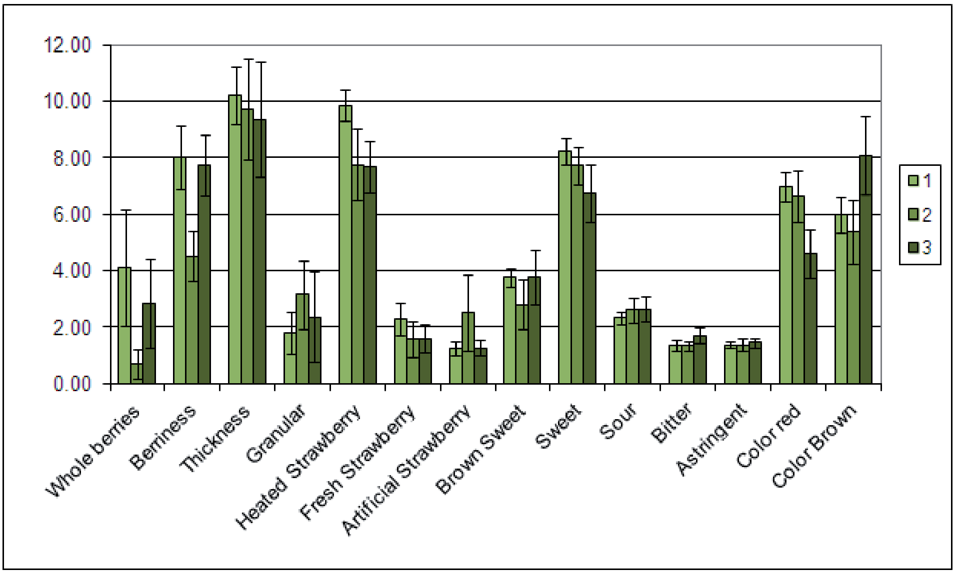

Fig. 4. Mean scores for cluster 1, 2, and 3 sensory properties. Error bars represent the standard deviation within one cluster.

Moderate to high correlations were found between the following instrumental measurements and sensory properties:

- sweet taste and total sugars (0.88), glucose (0.68), sucrose (0.71), Brix (0.89), dry weight (0.91),
- sour taste and titratable acidity (0.69),
- bitter taste and dry weight (-0.62).

The sweet taste correlation with sugar contents, Brix, and dry weight and the sour taste correlation with titratable acidity are quite straightforward; the negative correlation between bitter and dry weight could be explained by more intense bitter taste in case of lower dry weight and also related lower content of sugars. No correlation were found between sensory color and instrumental color measurements; cluster 3 was found brown in color, however, Table 4 shows no differences between the L, a, or b values between the clusters.

Strawberry jams were the second category that contained a number of products manufactured in Estonia. Comparison between Estonian and products manufactured elsewhere provides an understanding of possible local flavor identity. However, within the 25 strawberry jams studied, there were no patterns as far as similarities between jams manufactured within one country go (Paper III, Fig. 1). It rather seemed like different clusters of strawberry jams exist and these types are available in most countries; connections to manufacturing technology require further studies. Consumers prefer strawberry jams that are lighter in color, red, and sweet, and least accept low-calorie products and products with low sweet taste intensities (Alves et al. 2008). This suggests products in cluster 1 could possibly be more successful than products in clusters 2 and 3. However, some consumer segments may find specialty products, such as the products in cluster 3, acceptable as well.

Table 4. Strawberry jams clusters and strawberries mean chemical-physical and nutritional data.

Property	Cluster						
	Strawberries	1	stdev	2	stdev	3	stdev
L	N/A	38.03	0.40	38.27	0.22	38.14	0.35
a	N/A	0.28	0.05	0.34	0.12	0.28	0.08
b	N/A	2.07	0.04	2.04	0.05	2.07	0.05
TTA	0.60-0.97***	1.12	0.16	1.12	0.19	1.19	0.34
Brix, %	7.8-10.4**	54.14	6.69	53.68	12.01	36.19	15.44
pH	3.33-3.57**	3.54	0.09	3.48	0.22	3.64	0.17
Dry Weight, %	N/A	64.43	10.49	64.35	14.50	40.79	18.11
Citric acid	0.09-2.03***	0.36	0.05	0.21	0.14	0.34	0.07
Malic acid	0.12-0.54***	0.28	0.06	0.25	0.16	0.34	0.17
Total acid	1.6*	0.65	0.09	0.47	0.27	0.68	0.19
Sucrose	2.3*	20.44	5.82	16.55	7.20	4.05	4.99
Glucose	3.1*	11.47	2.64	12.32	3.65	6.03	5.50
Fructose	3.0*	10.14	1.95	11.85	5.51	13.07	9.33
Total sugar	8.4*	42.67	7.35	42.09	6.66	23.21	10.87
Hardness, g	N/A	184	234	120	41	133	55

Stdev – standard deviation within one cluster. L - luminosity, a - redness, b – yellowness, TTA – titratable acid value, *according to Fineli database (www.fineli.fi), N/A – not available, **Pilando et al. 1985, ***Kafkas et al. 2007. Acid and sugars contents g/100g.

3.1.4 Cheese Flavor and Clusters in Estonia and Europe

Cheese flavor research carried out within these studies emphasizes the importance of randomness for the consumers. All of the samples studied were commercial samples, and because of this the exact manufacturing data and technology were unknown. For most occasions the consumer has no information of the age of the cheese at time of purchase and could face a possibility the product is younger or older than expected, which may lead to disappointment with the product because of some unexpected sensory properties. Studies with cheeses acquired from retail facilities thus reflect the actual situation for the consumer. Variation within flavor characteristics was analyzed for different cheeses. In addition cheeses from different countries were clustered to map possible similarities and to characterize the overall cheese flavor variation within a country.

3.1.4.1 Flavor and clusters of Estonian cheeses

The flavor of cheeses manufactured in Estonia (Paper IV) was characterized as mild, with dairy and buttery notes. Still the Estonian cheeses studied could be divided into four flavor clusters (Table 5). Almost all mean scores for different attributes were in the weak range in intensity (0-4.5). When compared to each other, cluster 1 (n=17) was more pronounced in the sweet aromatics and cluster 4 (n=16) composed of pungent and butyric cheeses. However, both clusters 1 and 4 included a second dimension characterized by the sensory age attribute of cheeses (Fig. 1, Paper IV). The acceptance of cheeses in these two clusters is described in chapter 3.2.1. Cluster 2 was composed of one sample (198) and cluster 3 of two samples (775 and 431). Cluster mean scores show that sample 198, which was a surface-ripened cheese, was stronger in the aged, musty, moldy, sharp, bitter, butyric, and salty flavors. Samples in cluster 3 were smoked cheeses, which were strong in smoky flavor and also umami taste.

3.1.4.2 Flavor of cheeses manufactured in different countries

In another study (Paper V) the data on Estonian cheeses was added to four previous studies that described cheeses from different countries in Europe. This approach would evaluate whether the variations among the Estonian cheeses flavors were actually important when compared to other types of cheeses. Cluster analysis revealed four flavor clusters (Fig. 1, Paper V): clusters 1 and 2 were sour, dairy sour, salty, astringent, biting, and varied in buttery (cluster 1) and sharp notes (cluster 2). Cluster 1 and 2 were mainly composed of French cheeses, while clusters 3 and 4 represented cheeses from various countries. Cheeses in clusters 3 and 4 were sweet, with cooked milk and nutty characteristics and varied from buttery (cluster 3) to sharp notes (cluster 4). The Estonian cheeses were all part of cluster 4 with the exception of one mold-ripened sample that was included in cluster 1 with all other mold-ripened cheese samples. French and Italian cheeses seem most variable in flavor properties, as those cheeses were present in all clusters. However, for most countries that were represented with cheese samples, such conclusions could not be made as only a small number of samples were available for research.

Within cheese subgroups, in the semi-hard and semi-soft cheeses subgroup sample groupings by countries could be observed in the Principal Component Analysis (PCA). For example the Estonian cheese samples differed from samples manufactured in other countries by more intense cooked milk flavor, bitter taste, and astringency.

PCA analysis also showed similar discriminating attributes for overall cheese mapping, cow milk cheeses, other than cow milk cheeses, and soft-textured cheeses. These were cooked milk, biting, and moldy flavor, sour, and salty taste for PC1 and dairy fat, dairy sweet, musty/earthy, and sharp flavors for PC2. Although the overall sample set was fairly large (n=152), for some countries or cheese subgroupings further studies may be necessary to characterize cheese flavor properties.

Table 5. Mean scores for Estonian cheese flavor clusters.

Attribute/Cluster	1		2		3		4	
Buttery	3.4	a	3.7	a	3.1	b	3.3	b
Cooked Milk	3.0	a	3.0	a	2.8	a	3.0	a
Dairy Fat	3.9	a	4.0	a	3.4	b	3.6	ab
Dairy sour	4.5	a	4.7	a	3.9	c	4.3	b
Dairy Sweet	2.7	a	2.2	b	2.8	a	2.6	a
Aged	4.4	c	6.1	a	4.0	c	4.7	b
Butyric Acid	1.9	c	4.3	a	2.1	c	2.6	b
Dec. Animal	0.0	b	0.7	a	0.0	b	0.0	b
Fermented	0.1	c	1.0	a	0.2	c	0.6	b
Floral	0.9	a	0.4	bc	0.0	c	0.5	bc
Fruity	0.6	a	0.0	c	0.0	c	0.3	b
Green	0.0	b	0.4	a	0.0	b	0.0	b
Goaty	0.4	c	2.6	a	0.3	c	0.7	b
Musty	2.0	b	7.1	a	1.5	c	1.7	c
Moldy	0.4	b	8.6	a	0.0	c	0.4	b
Nutty	2.0	b	1.3	c	2.1	ab	2.2	a
Sauerkraut	0.0	b	0.0	b	0.1	a	0.04	ab
Smoky	0.0	b	0.0	b	5.5	a	0.0	b
Sweaty	0.3	c	3.3	a	0.6	b	0.6	b
Sweet aromatics	2.4	a	1.5	d	2.2	b	1.8	c
Waxy	0.8	c	0.3	d	1.2	b	1.5	a
Astringent	2.9	a	3.3	a	2.8	ab	2.7	b
Biting	2.1	c	3.3	a	1.9	c	2.2	b
Pungent	0.7	d	3.5	a	2.3	b	1.9	c
Sharp	3.3	a	3.9	a	2.4	c	2.7	b
Chalky mf	1.3	a	0.0	b	0.0	b	0.0	b
Sweet	0.8	a	0.8	a	0.7	a	0.5	a
Bitter	3.9	b	4.4	a	3.7	b	3.5	c
Salty	4.0	b	4.6	a	3.7	c	3.6	c
Sour	2.6	b	3.0	a	2.3	d	2.5	c
Umami	3.0	c	4.7	ab	5.2	a	4.6	b

Different letters within a row show significant difference between clusters for that attribute ($p<0.05$).

3.2 Characterization of Acceptance

Information concerning consumer acceptance of products can be added to data about product flavor variations to create a more thorough understanding of the profiles of potentially successful products among consumer groups.

3.2.1 Cheese Acceptance in Estonia (Paper IV)

Four samples were selected based on PCA map for the consumer acceptance study (Paper IV, Fig. 1). The consumers were clustered according to their flavor liking socres. Samples 201 and 150 were liked by cluster 2 (n=56) and samples 516 and 408 by cluster 1 (n=55). According to sample mean scores (data not shown), these samples were described by somewhat different flavor intensities. Samples 408 and 516 were higher in nutty, aged, and pungent properties than samples 201 and 150. Samples 201 and 150 were higher in buttery and dairy fat attributes than samples 516 and 408.

Liking for different flavor intensities in cluster 1 suggested most of the consumers thought sample 408 was “just about right” in flavor and dairy flavor, sour, sweet, and bitter taste intensity (Table 6). Only bitter taste intensity was found to be “too high”. Most consumers in cluster 1 also thought sample 516 dairy flavor, sour, sweet, and bitter taste are just about right. Those results suggest that consumers in cluster 1 liked cheeses that were low in dairy characteristics and higher in aged flavor and sweet taste. Those were the consumers who typically liked stronger flavored cheeses.

Cluster 2, however, was more complex. Samples 201 and 150 received higher mean liking scores (Table 1, Paper IV). Samples 201 and 150 were found just about right in flavor, dairy flavor, sour, sweet, and bitter taste (Table 6). Samples 408 (72.7%) and 516 (45.5%) were scored as too high in flavor intensity. 54.5% of consumers in cluster 2 found sample 408 and 45.4% sample 516 too strong in bitter taste. According to these results consumers in cluster 2 did not like the cheese having too sweet or too sour taste, or stronger-flavored cheeses overall.

Liking of different level of flavor intensity has been previously reported by Barcenas et al. (2001), who found that Spanish consumers liked ripened Idiazabal cheeses over younger cheeses; however, Gonzales Vinas et al. (1999) found that ewe-milk cheeses were liked better when the sensory characteristics were mild. Estonian consumers divided into two segments in their acceptance toward local cheeses; this was caused by their liking of flavor properties that typically define the age of the cheese. These results suggest there may be a consumer cluster interested in more intense-flavored cheeses than the regular Estonian cheeses. As the majority of Estonian cheeses were mild-flavored, a study comparing Estonian and imported cheese liking as was done by Ritvanen et al. (2005) may be appropriate to determine whether there is reason to invest into technologies that would result in surface ripened, highly aged, or other types of cheeses with strong or specific taste and aroma.

Table 6. Cheese samples flavor, dairy flavor, sour, sweet, and bitter taste intensity % for consumer cluster 1 and 2. Scores 1-2 are summarized as "too low", 3 as just-about-right (JAR), and 4-5 as "too high". JAR, too low, and too high % equals 100.

Cluster 1	Sample	150	201	408	516
Flavor	Too low	37.5	42.9	5.4	35.7
	Too High	21.4	26.8	17.9	17.9
Dairy fl	Too low	14.3	17.9	19.6	19.6
	Too High	26.8	30.4	3.6	21.4
Sour	Too low	17.9	19.6	10.7	23.2
	Too High	39.2	44.6	16.1	17.9
Sweet	Too low	39.3	51.8	14.3	17.9
	Too High	8.9	7.1	8.9	21.4
Bitter	Too low	16.1	17.9	5.4	8.9
	Too High	30.4	44.6	21.4	19.6
Cluster 2	Sample	150	201	408	516
Flavor	Too low	18.2	16.4	5.5	23.6
	Too High	16.3	32.7	72.7	45.5
Dairy fl	Too low	20.0	9.1	38.2	34.6
	Too High	23.6	27.3	30.9	25.5
Sour	Too low	10.9	16.4	9.1	32.7
	Too High	32.7	38.2	58.2	29.1
Sweet	Too low	34.6	30.9	34.6	18.2
	Too High	3.6	0.0	32.7	43.6
Bitter	Too low	9.1	14.6	7.3	16.4
	Too High	29.1	32.7	54.5	45.4

3.2.2 Acceptance of Pomegranate Juice (Paper VI)

According to Paper I, five flavor clusters can be distinguished among pomegranate juices. A sample from each of these was selected according to availability and subjected to an acceptance study in Estonia, US, Spain, and Thailand. Sample A was characterized as sour, musty/earthy, fruity-dark, and astringent. Sample B sensory properties included fruity with grape and cranberry flavors, and sour and sweet tastes. Sample C was characterized with beet and musty notes, but also sour and sweet tastes. Sample D had cranberry flavor, sour and bitter tastes, astringent mouthfeel, and was in addition fermented and metallic. Sample E carried fruity, candy-like and cherry notes, and was also evaluated as sweet and sour.

The liked pomegranate juices were sample B and E in Estonia and US, sample C in Spain, and sample B in Thailand (Table 3 in Paper VI). Two juices (A and D) were disliked in all four countries. Clustering of the consumers revealed some split opinions towards the samples (Table 5 in Paper VI). According to Fig. 1 in Paper VI, the sensory characteristics that differentiated the more liked samples from the less liked, were mostly related to fruitiness and sweet aromatics – cranberry, grape, and berry flavors. The samples that were not evaluated as pleasant, carried properties like sour, astringent, bitter, and fermented. According to Steiner (1979), the innate reaction to bitter taste is negative and to sweet taste is positive. The sample that was found acceptable in most countries, sample E, was characterized as high in combined sweet aromatics. According to the studies of Rozin et al. (1999), health and food concerns differ across cultures, and for example US consumers associated food strongly with health. Whether consumer acceptance correlates with actual health-inducing properties is a matter of a separate study. However, these results clearly accent the necessity of sensory analysis in final product evaluation and also the need for understanding consumer flavor choices.

The results of the check-all-that-apply (CATA) question for choices “I have no interest in buying this” and “I would consider buying this” are given in Fig. 5 and 6, respectively. These results indicate several things. First, the choice of not buying a sample resulted in a much stronger response than the option of buying a juice. Second, samples A and D were among the least desired juices within this study. For US consumers, though, this was also true for sample C. Third, sample B and also E were considered worth purchasing. While pomegranate juices are well known as healthy products, it was confirmed that purchase or repurchase is unlikely to occur if an unpleasant sensory experience has taken place.

There were some interesting differences within taste and flavor intensity ratings between countries. For example, sample E was evaluated as “too sweet” in US, Estonia, and Spain; however, in Thailand it was rated as “low sweet” (n=53) and “just about right” (n=37) in sweet taste intensity (Table 4, Paper VI). Sample E was found higher in overall sweet than other samples by descriptive profiling. Overall sweet represents an attribute, which is a combination of sweet taste intensity and sweet aromatics. For sour taste intensity the situation was reversed – while most Estonian, US, and Spanish consumers found sample E as “low sour” or “just about right”, 52 Thai consumers found the sour taste intensity “too strong”. This indicates Thai consumers may like sweeter products than European or US consumers.

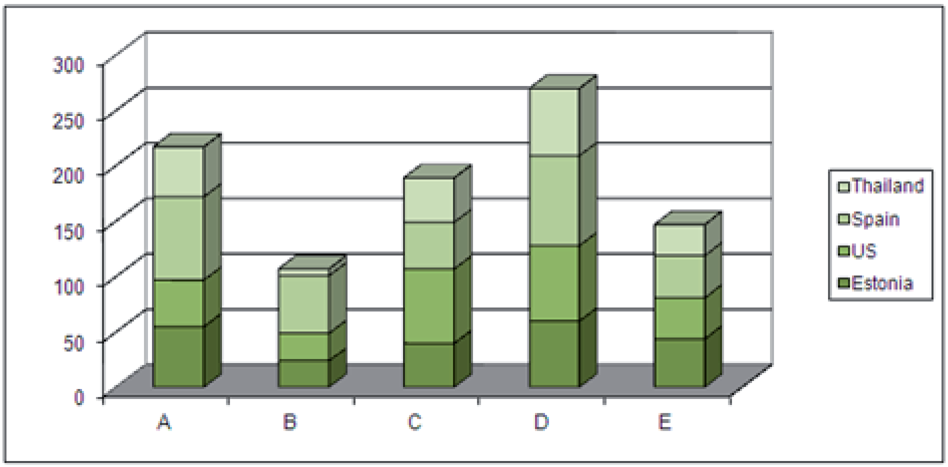

Fig. 5. Choice “I have no interest in buying this” results from the CATA question in the pomegranate juice acceptance study.

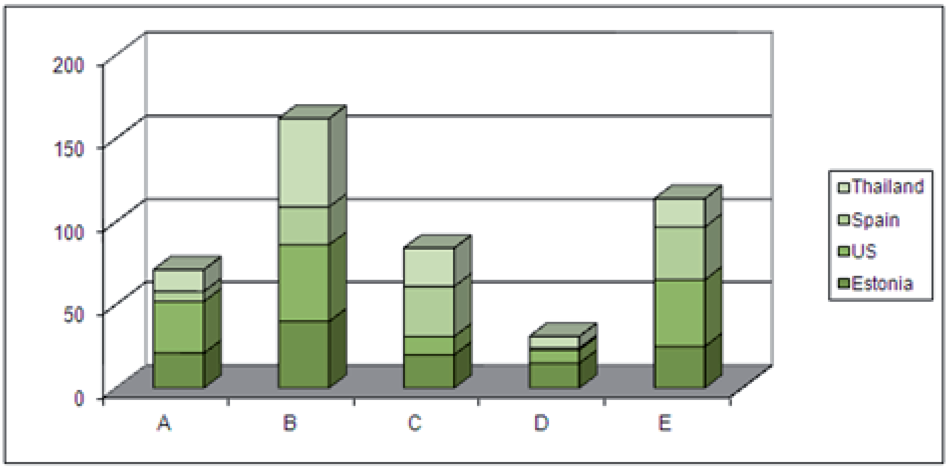

Fig. 6. Choice “I would consider buying this” results from the CATA question in the pomegranate juice acceptance study.

Strong taste and trigeminal sensations may have caused low liking ratings for some of the juices. More than half of consumers in Estonia, Spain, and US evaluated samples A, B, and D as “too strong” in flavor intensity; in Thailand samples A, C, D, and E were considered “too strong” in flavor by more than 50% of consumers. In addition a lot of consumers noted the astringency of samples A and D in all countries (Paper VI). This may be caused partly by basic taste sensations, but also the astringency and toothetch properties caused by the phenolic compounds in pomegranate juices (Viuda-Martos et al. 2010), and chalky mouthfeel present in sample C.

Different flavor combinations of pomegranate juices were liked in Spain (musty, fruit and vegetable flavors, sour, sweet), than in US, Thailand, and Estonia (fruity like grape and berries, sweet, and sour); however, a juice characterized by sweet aromatics, cherry and candy-like flavors, and sweet and sour taste was liked in most of the countries. Follow-up studies would possibly include freshly squeezed juices in comparison to the commercial pasteurized samples.

3.3 Evaluation of Methods and General Implications

3.3.1 Descriptive Analysis Methods

Two descriptive sensory analysis methods were used in this study: a traditional approach through descriptive sensory analysis, using sample repetitions, and the modified flavor profile method for analysis of flavor notes present in the samples. While the descriptive sensory analysis method requires more time, work, and amount of sample, it provides possibilities for statistical analysis of results, such as analysis of variance. Random mistakes should be fairly easy to detect when inspecting final scores and standard deviations within panelists. However descriptive sensory analysis can be susceptible to high variation or narrow use of the scale. In addition, differences in use of attributes to describe a certain characteristic cannot be monitored during testing because all scoring is individual. Flavor profile is fairly easily and quickly performed, but requires extensive training. Also statistically significant differences among samples cannot be determined as the panel output is in a single value format. The flavor profile method also has been criticized susceptible for random, and in some cases, systematic mistakes caused by the human factor, as it depends a lot on the panelists and their discussion regarding the flavor notes present in the samples, and thus possibly lowering the validity. However, one advantage of the method is that it allows panelists to discuss and agree on attributes and pinpoint nuances among products that might be lost with other methods. The validity of the modified flavor profile method would have been better if some of the sample measurements had been repeated to ensure repeatability.

The results from the flavor profile method indicated that a method that records different flavors and their intensities at different time-points could have provided extra information. Some of the tastes and mouthfeelings (bitter, sour, astringent) were noted at two different times – in the beginning and in the end of tasting. Such a method could be for example Temporal Dominance of Sensations (Labbe et al. 2009) or time-intensity studies that might provide some additional data that would help in understanding the flavor behavior of pomegranate juices and the most significant flavors present.

Two panels were used to carry out the studies. One in Sensory Analysis Center (SAC) in Kansas State University (Paper I, II, IV and VI) and the other in Competence Center of Food and Fermentation Technologies (CCFFT, Paper III). Both panels were trained; however, the panel in SAC had far more experience in analysis of different foods than the panel in CCFFT. Panel performance can be evaluated using comparison of a single score to the mean score, standard deviation follow-up within the scores, ANOVA interaction panelist*sample, PCA eigenvalues or plot (Tuorila and Appelbye, 2005). The standard deviation showed higher variation within the descriptive analysis scores of CCFFT panel (<2.0, calculated according to Paper III data) and lower for the SAC panel (<1.0, calculated according to Paper IV data). This was confirmed by ANOVA analysis, which showed there was some difference in scale usage between the CCFFT panelists while the SAC panelists used the same region of the scale. However, the samples tested varied in their nature: cheeses, which are more uniform in characteristics, were tested in SAC, and strawberry jams, which are higher in variation of fruit pieces and texture properties, were tested in CCFFT. In the results significant differences between samples were detected, still further training may have improved CCFFT panel performance. Thus the reliability, defined as the potential of the method of producing correct results, seems better for the SAC panel in descriptive sensory analysis.

Both of these descriptive methods were suitable for the objectives of the studies. Considering the strengths of both methods it may be suitable for food category appraisal to use the flavor profile method in the beginning of evaluations to develop the lexicon for the products in question. The initial data can also be used for mapping the products. In order to obtain statistically reliable data on specific attributes and their intensities, descriptive sensory analysis may be more appropriate. However, using both of these methods could be financially not possible and thus selection of a sample sub-set may become necessary.

3.3.2 Central Location Trial

Central Location Trials were performed in Paper IV and Paper VI. The CLT in comparison to HUT or laboratory-testing was a reasonable choice as the samples tested (cheese, pomegranate juice) were presented to the consumers in a ready-for-consumption format (no preparation required by the consumers), and the circumstance was not as unnatural as one would expect from a laboratory-testing.

The ballot for the consumers was fairly simple for Estonian cheeses (Paper IV), as it included seven questions about different flavor attributes liking and intensities and in addition a possibility to express their opinion. It was possible to measure acceptance as wanted. The ballot was more complex for pomegranate juices (Paper VI). For Paper VI the consumers were asked eight questions on flavor attributes liking and also intensities. However, it should be considered that an average consumer may not discriminate between different flavors or tastes (for example, pomegranate flavor) and unlike for the trained panelists, it is difficult for an average consumer to rate flavor intensities. In addition there was a section in the ballot with a check-all-that-apply question that included 42 different statements about the sample tested. The length of the ballot may have caused fatigue for some consumers, which could result in possible false results and also lower reliability of this method. Also, it would have been easier for the consumers to give a preference response concerning the pomegranate juice samples. However, the consumers were given adequate time to complete the questionnaire and using preference questions would have resulted in less information about why some samples were liked and others not.

Another issue in the ballot is the use of the 9-point hedonic scale, which is anchored with verbal descriptors "dislike extremely" and "like extremely". The word "like" translated into Estonian can have two meanings: it can characterize liking and pleasantness. As liking and pleasantness are highly correlated (Chrea et al. 2004) it was decided that translated words "ebameeldiv" and "meeldiv" in Estonian should be used in order to avoid the use of an expression "do not like extremely" in one end of the scale, which would have been not easily understandable.

3.3.3 Consumers

In consumers testing questions can arise as to whether the consumers represent the population or a suitable segment of the population. Consumers were recruited for CLT tests carried out with Estonian cheeses in Paper IV and pomegranate juices in Paper VI. The Estonian consumers (Paper IV) were recruited via emails and fliers in the capital area. For the cheese acceptance test the only precondition required was willingness to consume cheese. While the age range of the consumers was wide (18-65), the age distribution was tilted towards young adults (73%, age 18-35), while the Estonian population according to the statistics is aging (Statistical Yearbook of Estonia 2011), and approximately 24% of men and 20% women fall in the age range of 20-35. 71% of the consumers had higher education and 70% of the consumers were female, while according to the statistics 54% of population are women, and 38.5% of the working population has a higher degree (Eesti Statistika, 2011), so generalization of these results may apply more appropriately to educated younger Estonian population.

In the pomegranate juice study (Paper VI) the age range and education of consumers are in Table 7. The objective was to study acceptability among frequent juice drinkers. Gender distribution was approximately 40:60 men:women in all four countries. Age distribution varied by countries: most consumers in Estonia, Spain, and Thailand were in the age range of 18-45, while in the US 39.6% of consumers were in the age range of 46-65 or older. In Estonia, US, and Spain most consumers had college or higher education, but in Thailand most consumers had partial college education. When considering the population size in Spain, Thailand, and US compared to the size of the consumer panel, the results of this study probably cannot be generalized to wider population, but can be appreciated in a certain region. However, this is most often the case with consumer studies published.

Table 7. Consumer gender, age, and education distribution (%) in pomegranate juice consumer study (Paper VI).

	Estonia n=102	Spain n=100	Thailand n=110	US n=101
Male	41.2	40.0	36.4	45.5
Female	58.8	60.0	61.8	54.5
Age				
18-24	17.6	32.0	46.4	12.9
25-35	44.1	19.0	28.2	29.7
36-45	18.6	30.0	15.5	17.8
46-55	8.8	9.0	7.3	22.8
56-65	10.8	6.0	1.8	12.9
65 or older	0.0	4.0	0.0	4.0
Education				
High school or less	3.9	14.0	21.8	5.0
High school	13.7	6.0	10.0	6.9
Some college	10.8	16.0	55.5	20.8
College degree	22.5	23.0	10.9	39.6
Graduate degree	42.2	35.0	0.0	20.8
Professional degree	6.9	6.0	0.0	6.9

3.3.4 Samples

While the sample sets were fairly large for Paper I, III, IV, and V, the testing included samples from one production batch only. This could have reduced the number of flavors detected as different lots may vary in some extent in their flavor characteristics. A more thorough approach would have included several batches of each sample in different points of shelf life; this, however, would have increased the workload and time, as well as costs of these studies, making the studies impossible.

In Paper IV and VI the samples were transported to different countries for testing; this may have influenced product characteristics, especially for cheeses, although precautions to avoid warming were undertaken. According to the results the Estonian cheeses were mostly mild in flavor, which means excess maturation during transportation was avoided. Still some problems with transportation occurred, as one of the samples studied in Thailand (Paper VI) was different due to problems with transportation. This may have influenced the results of the study, as this sample was highly liked in Thailand, but the sample still represented the same flavor group as the one that could not be tested.

3.3.5 General Implications

The category appraisal approach using sensory methods, as described within this thesis, provides several perspectives for the general public, food and sensory scientists, the local food manufacturing companies, and global food manufacturing companies. This is the first work using sensory methods to help identify Estonian foods by their flavor. Estonian foods are mixture of neighboring countries, Russian, German, and Nordic cuisines for historical and geographical reasons (Raun, 2001). Comparison with foods manufactured in other countries suggests similarities in flavor profiles as was found with strawberry jams. The strawberry jams studied divided into three main groups according to their sensory properties, and these groups were not dependent on the country of manufacture (Paper III). The flavor profiles of Estonian cheeses in comparison with other European cheeses suggest Estonian cheeses may seem relatively familiar in their flavor to European consumers (Paper IV). On the other hand, the wide variety of flavors offered by cheeses manufactured in countries such as Italy and France (Paper V) may provide interest to one portion of Estonian consumers. Signature Estonian flavor profiles were not discovered within the foods studied, and this suggests more traditional food products should be studied, also because the importance of traditional foods is growing in Europe (Guerrero et al. 2009, Vanhonacker et al. 2010). It would be especially interesting to compare Estonian food flavor profiles with those countries flavor profiles with whom Estonians have interacted throughout history, such as a comparison of most popular cheeses in Estonia and in the neighboring countries. This kind of comparison would reveal whether there is some overlap in familiarity of flavors of traditional products across countries. The aspect of familiarity and familiar vs. novel flavors has been discussed by Tuorila (2007), Puumalainen et al. (2002), Arvola et al. (1999), and Tuorila, et al. (2001). Familiar flavors are liked more, which is very important in prediction of success and repeated purchase of a product. In addition, consumer response to new food product is related to previous experience with similar type of product (Bredahl, 2003; Verbeke, et al. 2010), or in the case of first time exposure, positive associations with already familiar attributes are crucial (Pliner and Stallberg-White, 2000).

Sensory instruments, such as measuring hedonic response and describing food flavors, are highly valuable tools for food manufacturers. These tools can be used to identify the flavors familiar to consumers in a certain region. Estonian food manufacturing companies are taking their first steps toward describing some of the food product categories in co-operation with food scientists (for example studies by AS Põltsamaa Felix, http://www.felix.ee/majonees/). Some foreign, but especially global companies have been practicing this approach for decades (Munoz et al. 1996, Moskowitz, 1996). The described results could be beneficial for both. Until now, most of the local companies have developed their products just by relying on the owners or leading managers' personal preferences, which makes product development not competitive in comparison with foreign or global companies (EAS report, 2011). Possible benefits for the local companies include better and more reliable understanding of the local market and the perspective for exporting local products. However, the most important information for local companies could be an introduction to the tools that make such studies possible.

Possible benefits for foreign or global companies include understanding the local market and consumers. As Estonia is such a small market (population appr. 1.5 million), it can be easily joined with most of the Eastern Europe representing consumers who should have same kind of attitudes toward food and other products. For some products, like strawberry jam, the preferences may not vary among countries, as long as the product introduced carries properties that are acceptable to consumers, as mentioned in Paper III. Similar consumer segmentation in different European countries has been found also by Causse et al. (2010). However, a different situation may occur, as found by Lee et al. (2010) and Semenou et al. (2007). An example of a product accepted in other countries but not in Estonia was not found within these studies, but an example was available for US and Thailand. One of the pomegranate juices, which was of Spanish origin, was not liked in US or Thailand probably because of chalky mouthfeel and musty/earthy flavor of the pomegranate juice. At the same time this juice was familiar and also accepted among Spanish consumers, suggesting regional flavor preferences as were also found by Puumalainen et al. (2002). Also, new products can be expected to be accepted in the markets where consumers have previous experiences with characteristic attributes of product in question (Hersleth et al. 2011). Most of the pomegranate juice samples presented were acceptable for Estonian consumers and this was probably caused by high awareness of healthy products or by the fact that pomegranates and pomegranate juices have been available in Estonia for decades, although one would suspect otherwise as pomegranates are not grown in Estonia. During the Soviet times import of various juice products from other Soviet countries was very common (there was even a commercial in television about pomegranate juice in 1985, found in Filmiarhiivi Infosüsteem). Thus the flavor of pomegranate juices, for example like sample A (Paper VI) which in fact was sold in Estonia, could have been familiar for the consumers who participated in the study.

CONCLUSIONS

Category appraisal through descriptive sensory analysis in combination with consumer acceptance studies provides understanding within the studied categories. Clustering the products according to their flavor properties and consumers according to their flavor acceptance allows obtaining ratings from products in the competitive frame and provides useful information to scientists and industries.

Within the categories studied (pomegranate juice, strawberry jam, and cheese) no strict flavor-country relationships were identified. Pomegranate juice category is versatile in flavors. Not all of the five flavor clusters identified within the pomegranate juice category were liked by the consumers. However, in each of the countries studied at least two of the flavor clusters were acceptable, probably because of familiarity or expected healthiness. Within the strawberry jam category one of the flavor clusters could be successful among consumers. However, the added value of specialty jams that clustered separately could be appreciated by a portion of consumers as well. Within the Estonian cheeses variation in flavor was a combination of several components, while the age characteristic of the cheeses seemed to define consumer acceptance. In comparison with European cheeses Estonian cheeses are quite homogenous in their flavor.

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DEVELOPMENT AND APPLICATION OF A LEXICON TO DESCRIBE THE FLAVOR OF POMEGRANATE JUICE

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ABSTRACT

A lexicon for describing the sensory flavor characteristics of pomegranate juices was developed. Thirty-three pomegranate juices, including concentrated products, products from concentrate, and freshly squeezed and pasteurized products, were studied. More than 30 sensory attributes were identified, defined, and referenced by a highly trained descriptive sensory panel. The lexicon that was established includes attributes to describe a range of flavors associated with pomegranates, such as brown spice, fermented, molasses, vinegar, wine-like, woody, apple, berry, cranberry, cherry and grape. Generally, pomegranate juice can be described by the flavor characteristics of sour, sweet, musty/earthy, fruity aromatics and an astringent mouthfeel. The flavor characteristics of pomegranate juices are reminiscent of a combination of concord grapes, cranberries, blackberries, cherries, currants and raspberries, but there also are vegetable notes such as beets and carrots. The lexicon provides attribute descriptors, definitions and references that were previously lacking in literature on pomegranates.

PRACTICAL APPLICATIONS

The manufacturing and consumption of pomegranate and pomegranate-based products has increased. Many products use pomegranate as a main flavor component or as an addition to other flavors in juices, yoghurts, jams and

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supplements. This research provides sensory terms that can be used to describe the flavor characteristics of pomegranate juices. This information is useful to product developers, researchers and technologists in understanding the characteristics of pomegranate flavor and using those attributes to create new products, adapt other products, and study quality-control and shelf-life issues.

INTRODUCTION

The health benefits of pomegranates are becoming widely known (Basu and Penugonda 2009). Pomegranate juice may improve stress-induced myocardial ischemia in patients who have coronary heart disease (Sumner *et al.* 2005), help fight diabetes-related conditions (Rosenblat *et al.* 2005) and carry anticarcinogenic properties (Adams *et al.* 2006; Pantuck *et al.* 2006). Research on pomegranates, the chemical composition of pomegranate juices, and the antioxidant properties of pomegranate juices have shown that commercial pomegranate juices have high antioxidant content and a high total phenolic content (Tezcan *et al.* 2009).

Researchers have also shown that there can be considerable variations in the antioxidant properties between different pomegranate cultivars (Ozgen *et al.* 2008). Different components of pomegranate juice, such as punicalagin and ellagic acid, have a positive synergistic effect on health (Seeram *et al.* 2004). Because of the health benefits, demand has increased production and consumption of pomegranate products. There are numerous pomegranate juices, concentrates and mixtures of juices available, providing the consumer with many options from which to choose.

Despite the popularity and considerable health benefits of pomegranate, little research on the descriptive sensory attributes of pomegranate juices was found. Data showing differences in chemical composition among pomegranate cultivars suggests that pomegranates may vary in their flavor properties as well. Martinez *et al.* (2006) described five new pomegranate varieties using attributes like seed hardness, visual color, taste, and overall quality appreciation. The aroma, taste, firmness, visual appearance, color, browning and dehydration of pomegranates were evaluated by López-Rubira *et al.* (2005) when studying the shelf life of pomegranate arils, which cover the pomegranate seeds and are edible. Singh and Sethi (2003) evaluated the mouthfeel of pomegranates in addition to the color and flavor in the sensory analysis of anardana – dried pomegranate seeds. Vardin and Fenercioglu (2003) studied the clarification of pomegranate juices and evaluated attributes like color, turbidity, overall appearance, bitterness and overall quality. Consumer acceptability was important for the studies of Hayaloglu and Vardin (2001) and Riaz and Elahi (1992) in the research of fruit punch with watermelon/pomegranate juice mixtures and carbonated pomegranate drink, respectively.

None of the studies included a detailed lexicon for the classification of the flavor attributes of pomegranate juice, although differences clearly exist. Thus, the objectives of this study were to (1) identify and define the sensory flavor attributes that characterize pomegranate juices and (2) describe and group different flavor profiles of commercially available pomegranate juice.

MATERIALS AND METHODS

Samples

Thirty-three pomegranate juice samples (Table 1) were used in this study. Twenty-seven of the juices were available in the U.S.A., although some were manufactured in other countries (predominately Turkey and Azerbaijan). One sample was obtained in Spain (Granavida Pomegranate Juice 100% Natural, #618), two samples were purchased from Estonia (4U Pomegranate Juice #115 and 100% Pomegranate Juice #175), and three samples were bought in Thailand (Brighty Pomegranate Juice #501, AC Fresh 100% Pomegranate Juice #289, and Dimes 100% Pomegranate Juice #416). Pomegranate juice with other added juices were excluded from the study in order to focus on the attributes of pomegranate specifically. However, nine of the samples contained natural flavors, nine were concentrated, and 15 were made from concentrate. One sample was enriched with fructose and two samples were made from organic pomegranates. All of the samples were assigned random three-digit codes. The products were obtained 3–4 weeks before testing and were stored according to the instructions given on the packages.

Sample Preparation

All of the samples were served at room temperature. Juices were shaken and poured into odor-free, disposable 92 mL plastic cups (Sweetheart Cup Co., Inc., Owings Mills, MD) covered with lids for the evaluation. Concentrated samples were prepared according to the instructions given on the packaging. The samples were prepared 30 min to 1 h prior to the testing. Each panelist received 57–85 mL of each product for evaluation. Additional sample was available if the panelists requested it.

Panelists

Five highly trained panelists from the Sensory Analysis Center, Kansas State University (Manhattan, KS) participated in this study. All of these panelists had completed 120 h of general descriptive analysis panel training with a variety of food products. This training included techniques and practice in

TABLE 1.
PRODUCT NAMES, TYPES AND ABBREVIATIONS OF THE EVALUATED POMEGRANATE JUICES

Sample #	Product name	Ingredients	Producer/country of origin
115	4U pomegranate juice	Pomegranate juice of first direct pressing	Gouzay-Sud ASC, Gousay, Azerbaijan
143	L&A all pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	Langer Juice Company Inc., City of Industry, CA
175	100% pomegranate juice	Pomegranate juice	ARAZ Imishli, Azerbaijan
190	Aveesa pomegranate juice	Fresh pressed pomegranate juice from whole ripe pomegranates. Potassium sorbate is added as preservative.	Aveesa LLC, Rutherford, NJ. Azerbaijan.
197	Jarrow pomegranate juice concentrate	Pomegranate Juice Concentrate	Jarrow Formulas, Los Angeles, CA
225	Puritan's pride pomegranate concentrate	Pomegranate concentrate, purified water, potassium benzoate, potassium sorbate	Puritans Pride Inc., Oakdale, NY
256	Pomegranate juice ziyad	Water, 100% pomegranate concentrate	Ziyad Brothers Importing, Cicero, IL. Turkey.
279	Lakewood organic pure pomegranate fresh pressed 100% juice	Fresh pressed juice from whole ripe certified pomegranates	Lakewood, Florida Family Trust, Miami, FL
289	AC fresh 100% pomegranate juice	100 % Pomegranate juice from concentrate	Thailand
324	RW knudsen family just pomegranate 100% premium pomegranate juice from concentrate, unsweetened, pasteurized	Pomegranate juice, filtered water (sufficient to reconstitute), pomegranate juice concentrate	Knudsen & Sons, Inc., Chico, CA
328	Langers pure 100% all pomegranate juice	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	Langer Juice Company Inc., City of Industry, CA
331	Pomegranate concentrate by culinary traditions	Pomegranate juice concentrate, filtered water	The Perfect Puree of Napa Valley, Culinary Traditions, Napa, CA
334	Heirloom farms 100% pomegranate juice	Pomegranate juice (pomegranate juice concentrate, filtered water), natural flavor	Opal International Ltd, Columbus, OH. Turkey.

TABLE 1.
CONTINUED

Sample #	Product name	Ingredients	Producer/country of origin
367	Elite Naturel: 100% organic natural pomegranate juice	100% Organic pomegranate juice	Elite Naturel Icecek, Ankara, Turkey. Organicjuiceusa.com
373	Northland 100% pomegranate juice pure pomegranate	100% Pomegranate juice (filtered water sufficient to reconstitute pomegranate juice concentrate), natural flavors, vegetable color	Northland Products Ltd, U.S.A.
388	Tree of life pomegranate concentrate	Pomegranate concentrate	Tree of Life Inc., St Augustine, FL
403	Earthly delights all natural pure pomegranate high in antioxidants; pomegranate juice from concentrate with natural flavours, gently pasteurized	Pomegranate juice concentrate, natural flavours, grape seed extract	Global Juices and Fruits, Eagle, ID
411	Lakewood pure pomegranate concentrate	Pomegranate Juice Concentrate, Vitamin C (ascorbic acid)	Lakewood, Florida Family Trust, Miami, FL
416	Dimes 100% pomegranate juice	100 % Juice from concentrated pomegranate juice (water 77,08%)	Thailand
442	Woodstock farms juice concentrate pomegranate	Pomegranate juice concentrate	Woodstock Farms, Dayville, CT
488	Life extension pomegranate juice concentrate	Pomegranate juice concentrate, purified water	Quality Supplements and Vitamins Inc., Fort Lauderdale, FL
501	Brighty pomegranate juice	Pomegranate 85%, fructose 15%	Thailand
520	Elite naturel: 100% natural pomegranate juice	100% Pomegranate juice	Elite Naturel Icecek, Ankara, Turkey. Organicjuiceusa.com
555	RW knudsen pomegranate juice concentrate	Pomegranate juice concentrate	Knudsen & Sons Inc., Chico, CA

TABLE 1.
CONTINUED

Sample #	Product name	Ingredients	Producer/country of origin
566	POM Wonderful 100% pomegranate juice from concentrate with added natural flavours, flash pasteurized	Pomegranate juices from concentrate and natural flavours	POM Wonderful, LLC, Los Angeles, CA
618	Granavida pomegranate juice 100% natural	100% Elche pomegranate extract, direct extract (not derived from a concentrate)	Granadas de Elche, SLU, Las Bayas Elche, Alicante, Spain
655	Swanson pomegranate juice	Reconstituted pomegranate fruit concentrates, purified water, potassium benzoate and potassium sorbate (to retard spoilage)	Swanson Health Products, Fargo, ND
707	Old orchard premium pomegranate juice	Pomegranate Juice from concentrate (filtered wter, pomegranate juice concentrate), natural flavours, ascorbic acid (vitamin C), vitamine E acetate	Old Orchard Brands, LLC, Sparta, MI
739	Archer Farms Pomegranate 100% juice from concentrate with natural flavor	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavor.	Target Brands Inc., Target Corp., Minneapolis, MN
843	Indo-European Pomegranate Juice	Pure pomegranate juice and pomegranate concentrated blend	Indo-European Foods, Inc., Glendale, CA
846	Whole foods 365 100% juice pomegranate	Pomegranate juice from concetrate (filtered water, pomegranate juice concentrate), natural flavor	Whole Foods Market, Austin, TX
943	Hyson pomegranate juice	Fresh squeezed pomegranate juice, potassium sorbate	Hyson USA Inc., Arlington Heights, IL. Pomegranate origin = Turkey.
981	Dynamic health pomegranate concentrate	Pomegranate juice concentrate	Dynamic Health Laboratories, Inc., Brooklyn, NY

attribute identification, terminology development, and intensity scoring. Each of the panelists had more than 1,000 h of testing experience with a variety of food products. For this study the panelists also received further orientation on fresh and processed pomegranates.

Terminology Development and Description

The descriptive terminology for this study was developed initially using only seven of the pomegranate juice samples. Various descriptive references were provided for the panelists. While some references were proposed by the panelists and were based on previous work and experience, others were added to the lexicon during this initial lexicon development phase. Five 1.5 h orientation sessions were held to establish the initial attributes and descriptive references for pomegranate juices. Recent studies by Hongsoongnern and Chambers (2008a, 2008b); Talavera and Chambers (2009); Thompson *et al*. (2009); Dooley *et al*. (2009) and Civille *et al*. (2010), have used similar attribute determination and description procedures as the ones used in this study.

Sample Evaluation Procedure

Twenty-one 1.5 h sessions were held for evaluation of the samples. Only one to two samples were evaluated during each session in order to reduce the carryover of flavors. All samples were evaluated once, although multiple servings of the sample could be served during that one time period. All of the samples were coded with three-digit random numbers and the order in which the products were evaluated was randomized. The panelists were allowed to add attributes to the descriptive terminology if new flavors were found in samples they tested.

A modified flavor profile method used by Talavera and Chambers (2009) and Hongsoongnern and Chambers (2008b), using a scale with 0.5 increments where 0 represents none and 15 extremely strong, was used to measure intensity. This consensus profile method is particularly useful in lexicon development studies because new attributes can be easily added, defined, and referenced when they appear in products the panel is seeing for the first time.

Each sample was evaluated for the flavor attributes that were present in the sample and each panelist individually assigned intensities to the attributes according to the flavor references included in the lexicon. All of the recorded attributes and their intensities were discussed by the panel. Often the evaluation of the sample would continue into the next session because of strong carryover. In cases where a new attribute emerged, a discussion between the panel leader and the panelists, using the consensus approach, would focus on the appropriateness, definition, references and evaluation technique of that attribute.

Data Analysis

The Statistical Analysis System version 8.2 (SAS, Cary, NC, 2001) was used for clustering the samples and for the correlation analysis, using Pearson correlation coefficients. The Unscrambler version 9.7 (Camo Software, Norway) was used for principal component analysis (PCA). Clustering of the samples was done by using the CLUSTER procedure (Ward's Minimum Variance Cluster Analysis). The number of clusters was set according to the eigenvalues of the correlation matrix (>1). Attributes that were scored in seven or fewer products (approximately 20% of products, 22 of 36 attributes) were excluded from the analysis because they tend to force the multivariate statistics into separating unique attributes rather than the overall pattern of attributes and intensities. Using these criteria means that the overall pattern of common pomegranate flavors is evaluated, but potentially characterizing attributes must be examined further by the researchers on a case by case basis. This points to a problem when using PCA: it can be overly sensitive to attributes that are unique to only a few products and can lose the overall structure of the data. It is critical for papers to explain the impact of decisions related to attribute selection. In addition, it is crucial to examine the other attributes to determine what they may add to understanding of the unique properties of the products.

RESULTS AND DISCUSSION

The initial lexicon based on the small initial set of juices included 15 attributes: sweet, sour, bitter, astringent, umami, toothetch, fruity, tomato, cranberry, grape, beet, fruity-dark, green-viney, musty/earthy and fermented. Tomato and umami, included in the initial lexicon, were not scored during the evaluations and hence these attributes are not included in the final lexicon. Several attributes were added to the lexicon during the testing: apple, berry, brown spice, brown sweet, carrot, candy-like, cherry, floral, molasses, sweet overall, vinegar, wine-like, woody, metallic, metallic mouthfeel, chalky mouthfeel, pungent, tongue tingle, tongue numb and throat burn (Table 2).

Most of the attributes are self-explanatory using the information in Table 2. However, several attributes may need further explanation. For example, the berry attribute was added to the lexicon because the panelists needed an attribute to describe a general, unidentifiable berry flavor. This attribute describes sweet, sour, and sometimes darker aromatics associated with a variety of berries. Thus, a general berry term was added to describe this overarching flavor.

The attribute vinegar often was accompanied by the mouthfeel attributes tongue tingle, tongue numb or throat burn. These may have been the result of

TABLE 2.
POMEGRANATE JUICE ATTRIBUTES, DEFINITIONS, REFERENCES AND INTENSITIES ON A 15-POINT SCALE

Attribute	Definition	Reference
Apple	A sweet, light, fruity, somewhat floral aromatic commonly associated with processed apple juice and cooked apples.	Gerber applesauce = 6.0 (flavor)
Beet	The damp, musty/earthy, slightly sweet aromatics commonly associated with canned/cooked beets.	Diluted kroger canned beet juice (1:2) = 4.0 (flavor)
Berry	The sweet, sour, sometimes dark aromatics associated with a variety of berries such as blackberries, currants, raspberries etc, excluding cranberries.	Blackwell red currant jelly = 8.5 (flavor)
Brown Spice	Aromatics associated with a range of brown spices such as cinnamon, nutmeg, cloves and allspice.	McCormick spices, mixed = 13.0 (aroma). Preparation: combine $^1/_4$ tsp of cinnamon, $^1/_4$ of ground cloves, $^1/_4$ of ground nutmeg and $^1/_4$ of allspice in a vial, shake well to combine. Serve $^1/_4$ tsp of this mixture in a medium snifter, cover.
Brown sweet	Sweet brown aromatics that may include the character notes identified as caramelized and commonly associated with honey, brown sugar, caramel, or other products that have been non-enzymatic browning.	Dark Karo syrup = 10.5 (flavor) C&H golden brown Sugar = 8 (flavor) C&H dark brown sugar = 9.5 (flavor)
Carrot	The aromatics commonly associated with canned, cooked carrots.	Del monte sliced canned carrots = 7.0 (flavor)
Candy-like	A sweet aromatic often associated with processed essential oils and usually found in candy products such as Jell-O and Kool-Aid.	Jell-O strawberry gelatin (powder) = 7.5 (flavor)
Cranberry	The sweet, fruity, slightly sour and sharp aromatics commonly associated with cranberries.	Ocean spray dried cranberries = 9.0 (flavor) Old Orchard's frozen cranberry concentrate = 7.5 (flavor) old orchard's frozen cranberry conc diluted (1:1) = 3.5 (flavor)
Cherry	The sour, fruity, slightly bitter aromatics commonly associated with cherries.	RW knudsen cherry juice diluted (1:2) = 4.0 (flavor)
Fermented	Pungent, sweet, slightly sour, sometimes yeasty/alcohol like aromatics characteristic of fermented fruits or sugars or over-proofed dough	Frank's Sauerkraut (juice only, diluted + 6.5 (flavor). Preparation: Drain juice from solids and mix 1 part juice to 2 parts water
Floral	Sweet, light, slightly perfumey impression associated with flowers.	Humco artificial rose/water diluted 1:10 = 6.0 (aroma) (1 drop on cotton ball in medium snifter, covered); Geraniol (10,000 ppm = 7.5 (aroma) 2 drops on cotton ball in lg. snifter, covered)

TABLE 2.
CONTINUED

Attribute	Definition	Reference
Fruity	A general term used to describe the sweet, floral, fruity aromatics associatedwith a blend of fruits.	DelMonte lite chunky mixed fruits, preparation: drain fruits, mix juice with water 1:1. juice = 5.5 (flavor). Jello mixed fruit, prepared according to package. Instructions = 8.0 (flavor). Fruit mixture = 10 (aroma). Preparation: mix in a medium snifter, cover: 1 strawberry from Kelloggs special K red berry cereal; mariani dried cherry; ocean spray dried cranberry; sun maid raisin; and 1/3 piece sunmaid mission
Fruity-dark	The sweet, brown honey/caramel-like aromatics commonly associated with dark fruits such as raisins and prunes that have been cooked.	Mixture of sun maid raisins, prunes, ocean spray cranberries and water: juice = 5.0. Preparation: mix of $^{1}/_{4}$ cup raisins, 1/3 cup dried cranberries and 1/4 cup of prunes (chopped), add $^{3}/_{4}$ cup of water and cook on high for 2 min. Pour juice into 1 ounce cups, cover with lid.
Grape	The sweet, brown, fruity, musty aromatics commonly associated with grapes.	Welch's concord grape juice = 9.5 (flavor) Welch's concord grape juice diluted (1:1) = 5.0 (flavor) Welch's white grape juice diluted (1:1) = 5.0 (flavor)
Green-viney	A green aromatic associated with green vegetables and newly cut vines and stems; characterized by increased bitter and musty/earthy character.	Trans-2-hexen-1-ol 5,000 ppm = 4.0 (aroma). Fresh sliced tomatoes = 10.0 (flavor), 9.0 (aroma)
Honey	Sweet, light brown, slightly spicy aromatics associated with honey.	2 Teaspoons busy bee honey in 250 mL water = 6.5 (flavor).
Metallic	The impression of slightly oxidized metal, such as iron, copper and silver spoons.	Dole canned pineapple juice, unsweetened = 6.0 (flavor)
Molasses	Dark, caramelized top notes that are slightly sharp and characteristic of molasses.	Grandmas molasses = 6.5 (flavor) Mix 2 teaspoons of molasses in 250 mL water
Musty/earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar-like characteristics.	Raw potatoes = 3.0 (aroma). 100 ppm geosmin = 8.5(a) (Dip perfumer strips in geosmin solution and place in individual test tubes for each panelist).
Pungent	A sharp, physically penetrating sensation in the nasal cavity.	Heinz white vinegar : water 1:8 dilution = 8.0 (aroma)

TABLE 2.
CONTINUED

Attribute	Definition	Reference
Sweet, overall	The perception of the combination of sweet taste, sweet aromatics, caramelized, brown sugar, honey, and maple.	White pear grape juice diluted (1:1) = 4.0 (flavor). Lorna doone cookie = 5.5 (flavor) C&H pure cane golden brown sugar = 9.0 (flavor). 12 C&H golden brown sugar solution = 11 (flavor). Torani sugar free classic caramel flavoring syrup = 14 (flavor)
Vinegar	Sour, astringent, slightly pungent aromatics associated with vinegar.	Heinz white vinegar diluted (1:12) = 8.0 (flavor)
Wine-like	Sharp fruity alcohol-like aromatics associated with red wine.	Regina cooking wine = 10.0 (aroma)
Woody	The aromatics associated with dry freshly cut wood.	Forster craft stick = 7.5 (aroma)
Sweet	The fundamental taste factor associated with a sucrose solution.	2% sucrose solution = 2.0 4%. sucrose solution = 4.0
Sour	A fundamental taste factor of which citric acid in water is typical.	0.025% Citric acid solution = 2.5 0.05% Citric acid solution = 3.5 0.08% Citric acid solution = 5.0 0.1% Citric acid solution = 7.0
Bitter	The fundamental taste factor of which caffeine or quinine is typical.	0.01% Caffeine solution = 2.0 0.02% Caffeine solution = 3.5 0.035% Caffeine solution = 5.0 0.05% Caffeine solution = 6.5
Astringent	The dry puckering mouthfeel associated with an alum solution.	0.05% alum solution = 2.5 0.1% alum solution = 5.0 0.15% alum solution = 7.5
Toothetch	A sensation of abrasion and drying of the surface of the teeth.	Welch's grape juice diluted (1:1) = 6.0 (flavor)
Metallic	A mouthfeel and aromatics associated "tin" cans, iron copper, or oxidized silver.	Silver spoon placed in the mouth = 7.0 (flavor). 0.01 g ferrous sulfate in 1,000 mL water = 5.0 (mouthfeel)
Chalky	A dry, powdery sensation and an aromatic associated with mineral salts such as chalk. Can be on mouth and /or teeth.	Corn starch solution = 3.0 Mix 1 g of corn starch in 100 mL water. Pour in 1 ounce cups, cover with lid.
Tongue tingle	A feeling of an increased sensation on the tongue that may be due to intense carbonation or other causes. Evaluate during first 3–5 s after sample is placed in the mouth.	7-Up = 8.5
Tongue numbing	Loss of sensation on tongue evaluated after swallowing the sample	7-Up = 5.5
Throat burn	The chemical feeling factor described as a burning sensation perceived in the throat.	Heinz white vinegar diluted (1:12) = 4.0

organic acids present in the product. One difficulty with the vinegar attribute was that the panelists initially defined the vinegar attribute as including pungency, which is part of the overall impression when smelling vinegar. However, during evaluation, the panelists had difficulty agreeing on vinegar intensities because in many cases the vinegar flavor was present in the samples but the pungent aromatics were lacking. Thus, "vinegar" flavor aromatics and "pungent" need to be separate attributes in the lexicon when conducting further research on pomegranate juice. The definition of vinegar was modified in the lexicon and the term pungent was added to reflect this necessary change.

The wine-like attribute was added to the lexicon as there was a need to describe aromatics associated with red wines. There was a discussion among the panelists whether the attribute wine-like could be distinguished from the attribute fermented, which was already in the lexicon. It was decided that the fermented attribute described the aromatics associated with yeasty over-proofed dough or fermented vegetables or fruits as opposed to the overall "wine-like" note found in red wines.

The overall fruit complex attribute was used as a general term to describe the sweet, floral and fruity aromatics associated with a variety of fruits. This term was used in the case of three samples (739, 403 and 256) to express the overall fruitiness combining different notes that could not be distinguished otherwise. Although the panelists indicated that a fruity complex and fruitiness were different attributes, they were not able to describe the difference well enough to propose separate definitions that could be used by others. Thus, we chose not to include fruity complex as a separate term.

Three samples (225, 175 and 416) were noted to be "watery", which the panel initially described as a weak non-descript flavor. However, such an attribute is not necessary to add because it can be inferred from low scores on other attributes.

The attribute chalky mouthfeel often is considered a textural property. In this study, it was first noted in a product that also had large flakes, resulting in high amounts of residuals in the cup. However, two other samples that did not have residue were noted as chalky, and the panelists indicated they felt it was aromatic in nature and different from a textural characteristic. This suggests that the aroma of certain compounds may provide a chalkiness that is part of flavor. Thus, it appears that chalky can be either a texture (physical particulate) or flavor (aromatic).

Some attributes were characteristic for only a small number of samples (Table 3). These attributes represent a variety of flavor notes and mouthfeel attributes that may result from processing conditions, pomegranate variety, or the age of the fruit and the product. Attributes such as green-viney, cherry, apple, carrot, floral, candy-like, brown sweet, brown spice and molasses indicate the range of different flavors that are available to consumers of pome-

TABLE 3.
ATTRIBUTES, THAT WERE NOTED IN 7 OR FEWER POMEGRANATE JUICE SAMPLES

Sample #	Attributes
175	Candy-like
190	Chalky mouthfeel, vinegar, woody
197	Astringent, chalky mouthfeel, molasses, woody
225	Apple, metallic, throat burn, tongue tingle, vinegar
289	Astringent, carrot, woody
324	Carrot, green-viney, metallic, metallic mouthfeel
331	Astringent
367	Carrot
373	Brown spice, floral, throat burn
388	Throat burn, vinegar, woody
411	Brown sweet, molasses, vinegar, woody
416	Candy-like, floral, woody
442	Brown sweet, molasses, woody
488	Astringent, bitter
501	Brown sweet, candy-like, cherry, floral
520	Carrot, chalky mouthfeel
555	Throat burn
566	Astringent, floral
618	Metallic, metallic mouthfeel
655	Throat burn, tongue tingle, tongue numb, vinegar
707	Astringent, bitter, floral, metallic, metallic mouthfeel
739	Apple
843	Metallic
846	Apple, cherry, floral
981	Candy-like

granate juice. The attributes chalky mouthfeel, metallic mouthfeel, throatburn, woody, vinegar and tongue tingle also were not detected in most of the pomegranate juices, but were found in a few.

The bitter attribute was present in all of the samples and usually was sensed at the end of tasting the sample. However, for some samples (488 and 707) the bitter taste also was noted in the beginning of tasting. These bitter taste scores are also given in Table 3.

Molasses was used to describe the dark, caramelized, sharp notes. The concentration technology of the pomegranate juice is of high importance in terms of the final quality of the product as it greatly influences the flavor, aroma, color, appearance and mouthfeel of the product (Jiao *et al*. 2004). Five of the concentrated samples were a brown color and two were a brown/red color. The brown color can be associated with the attribute molasses as that note is related to highly concentrated, heated plant products containing sugars. The attribute molasses was noted three times and only in the case of concentrated products. In addition to molasses, the panel determined that an attribute other than molasses that described brown, sweet aromatics without the dark, almost burnt and sulphury character of molasses was needed. Thus, “brown sweet” was included.

The aromatics of honey and caramel were noted when evaluating one sample. The panelists discussed whether it is necessary to introduce these two new attributes to the lexicon. Although references were proposed for these attributes, the panelists decided not to include these aromatics as separate attributes because they were already covered in attributes such as dark fruit and brown sweet. However, in hindsight we believe that honey is a distinctly different attribute and should be included as a separate term in the lexicon. Thus, we have included honey as an attribute in the lexicon, but it was not scored for any of the products in this test.

During the evaluation, the panelists occasionally did not agree on the flavor notes present in the samples. This occurred for six attributes: wine-like, beet, floral, brown spice, fermented and molasses for specific products. Such an occurrence suggests that the attribute was not be as well defined or referenced as it should have been because some panel members interpreted the attribute differently from other panelists. When this happened, the panel re-defined or re-referenced the attributes and re-evaluated samples to ensure consensus was reached.

Correlation and PCA of Pomegranate Juices

Figures 1 and 2 present principal components (PC) 1–4. The first four PCs explain 70% of the variation in the flavor attributes. PC1 differentiates between the dark-fruity characteristics versus those associated with grapes and berries. PC2 separates samples according to the higher overall sweetness of the samples versus the lower or less sweet samples. The berry attribute versus the grape attribute is differentiated by PC3 and PC4 distinguishes between the fermented characteristics and the musty/earthy, beet-like notes.

Most of the correlations among attributes for the pomegranate juices were low indicating that the attributes were describing different characteristics in the pomegranate juices. Few correlations exceeded a moderate level of approximately 0.50. Candy-like was positively correlated to sweet overall ($r = 0.79$) and negatively to sour ($r = -0.64$) and sweet and sour were negatively correlated ($r = -0.69$). Both of these attributes also were negatively correlated with bitterness and astringency.

Attributes that were measured in dual ways or were measured twice (early and late in the profile) tended to be more highly correlated than other attributes. For example, metallic mouthfeel and metallic flavor were highly correlated ($r = 0.87$). In most of the samples where metallic flavor was noted, a metallic mouthfeel was scored as well. This indicates the possibility of

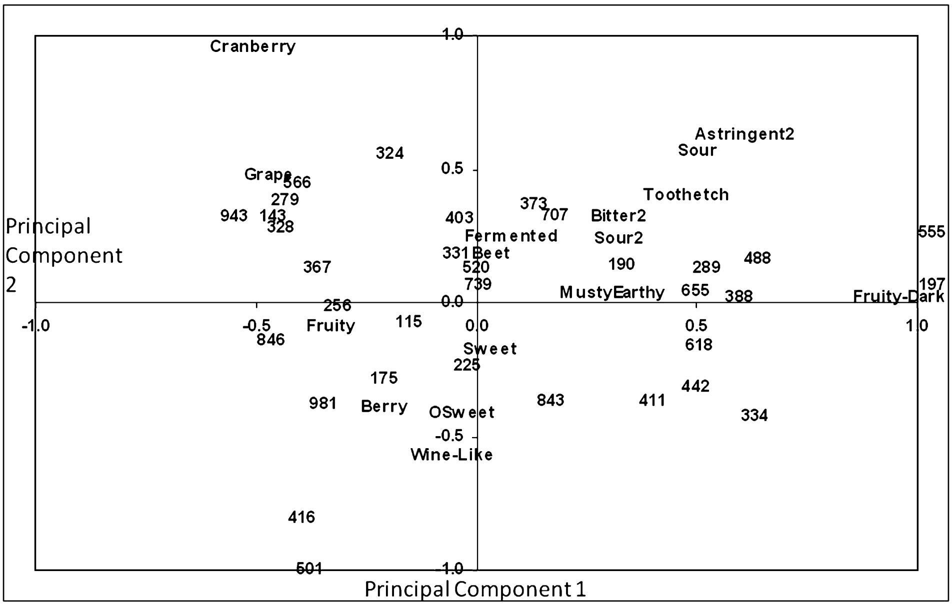

FIG. 1. PRINCIPAL COMPONENTS MAP OF PRODUCTS ON DIMENSION 1 (EXPLAINS 29% OF THE VARIATION) AND DIMENSION 2 (EXPLAINS 18% OF THE VARIATION)
Note: Astringent2 – astringent mouthfeel noted in the end of sample tasting. Bitter2 – bitter taste noted in the end of sample tasting.

recording similar impressions twice. However, as the panelists differentiated between these two attributes and there were two samples that were scored for metallic flavor, but not metallic mouthfeel, both of these attributes probably should be kept in the lexicon. Similarly, there was a high correlation of 0.78 between the first sour impression (noted rarely) and the astringent mouthfeeling found at the end of tasting. The same was also true for the bitterness and astringency found at the end of tasting the sample (0.89). A correlation of 0.72 is present between the sourness and bitterness scored at the end of sample tasting. All of the samples were scored for the attributes sour and bitter and only two of the samples were not scored for astringency. These correlations and the initial scores indicate that sourness, bitterness and astringency are part of the nature of pomegranate juices and likely are found in tandem with each other.

Clustering Pomegranate Juices

Some of the samples in cluster 1 (Table 4, samples 334, 442, 403, 289, 331, 388, 843, 618, 115 and 411) are characterized by berry and fruity-dark (Fig. 1) attributes. According to PC2, these samples could be described as

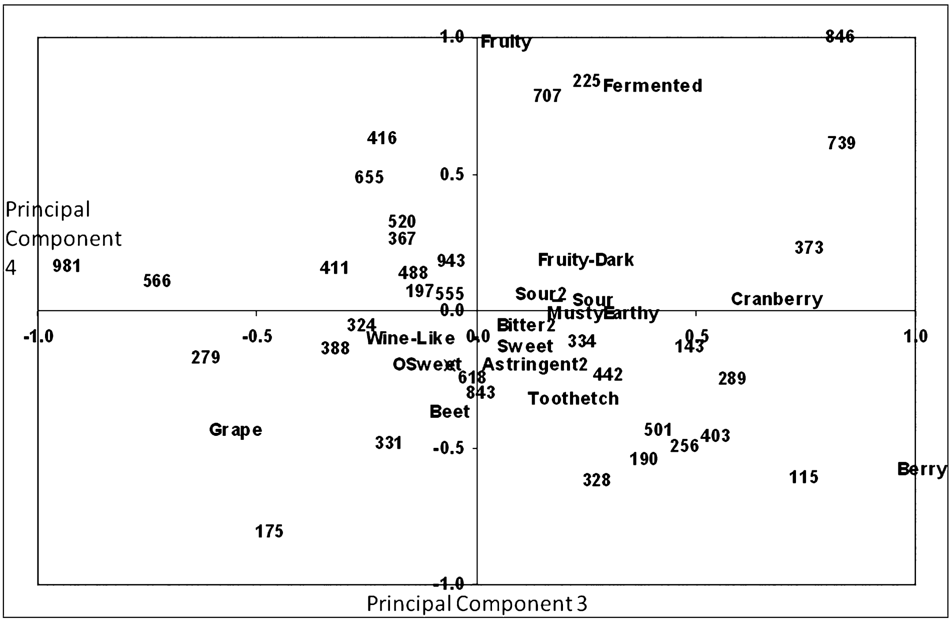

FIG. 2. PRINCIPAL COMPONENTS MAP OF PRODUCTS ON DIMENSION 3 (EXPLAINS 13% OF THE VARIATION) AND DIMENSION 4 (EXPLAINS 10% OF THE VARIATION)
Note: Astringent2 – astringent mouthfeel noted in the end of sample tasting. Bitter2 – bitter taste noted in the end of sample tasting.

TABLE 4.
CLUSTER ANALYSIS RESULTS OF POMEGRANATE JUICES (SEMI-PARTIAL R SQUARED <0.05)

Cluster no	Sample no	Differentiating attributes
1	115, 289, 331, 334, 388, 403, 411, 442, 618, 843	Berry, dark-fruity, toothetch mouthfeel
2	143, 256, 279, 324, 328, 367, 520, 566, 943	Grape, cranberry, wine-like
3	225, 373, 655, 707, 739, 846	Fermented, toothetch mouthfeel
4	190, 197, 488, 555	Brown color, musty/earthy
5	175, 416, 501, 981	Candy-like, sweet overall

sweet and also overall sweet when fruity-dark and berry notes are added to the sweet flavor. Cluster 2 (samples 328, 256, 143, 943, 279, 324, 520, 367 and 566) is composed of samples that are characterized by grape and cranberry (Fig. 2) attributes and were colored red or purple. Fermented and toothetch properties are characteristics of samples in cluster 3 (samples 739, 846, 655, 225, 707 and 373). This group of samples cannot be related to certain attributes like grape, fruity-dark, sweetness or berry according to Fig. 1. However, Fig. 2

suggests that the fermented attribute explains the similar traits of these samples. The samples in cluster 4 (samples 197, 555, 488 and 190) were brown in color and had low intensities of the musty/earthy attribute. Three of these samples (all except 190) were products of concentrate, suggesting they were heated extensively before being made into juice, which might explain the brown color. Cluster 5 (samples 501, 416, 981 and 175) is composed of samples that are candy-like. The sweet overall values of these samples are in the moderate range (scores 6–8). Samples that are in this cluster are located close to the overall sweet (OSweet) attribute in Fig. 1. No scores of cranberry, dark-fruity or fermented attributes were given to these samples and this could explain the separation into an extra cluster.

The clustering results suggest that the pomegranate juices can be divided into groups that are characterized by distinctive sensory attributes. In general, those seem to be driven by processing. However, differences in original solids content, cultivar, or location might become more important if a more focused set of samples or known original fruit were chosen. Most of these groups appear logical based on the PCA results. It is clear that pomegranate juices are sweet, sour, bitter, astringent, and have toothetch. Although the flavors can be complex, the major components are grape, cranberry, berry, fruity-dark, musty/earthy and beet.

CONCLUSION

A sensory lexicon for pomegranate juice evaluation was developed. The 34 referenced and defined attributes can be helpful for scientists, technologists and product developers in working with and understanding pomegranate or pomegranate-based products. However, all of these attributes might not be necessary when studying a certain product and a selection should be made accordingly. Some of the attributes found in several samples in this study might not be appealing from a consumer's point of view and this information could be helpful in developing production technologies, clarification and the concentration methods of pomegranate juices.

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Article II

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Instrumental and sensory aroma profile of pomegranate juices from the USA: differences between fresh and commercial juice

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ABSTRACT: Fourteen pomegranate juices (one fresh-squeezed and 13 commercial juices) were studied to determine the aromatic profile of the products. Headspace–solid phase micro-extraction and sensory flavour profile analysis were used to determine the aromatic composition of the juices and were related using partial least squares regression. Up to 83 different aromatic compounds were found in the juices, including terpenes, benzene derivatives, furans, esters, acids, ketones, alcohols and aldehydes. Commercial pomegranate juices did not present a unique sensory or instrumental aromatic profile. The three attributes common to the majority of the juices were an overall sweetness and musty/earthy and grape notes. This study shows the large heterogeneity of the pomegranate juices found on the market, which might be related to the fact that companies are looking for different successful pomegranate juice products using different raw ingredients and processes. Further studies are required to clarify what consumers are expecting in a typical 'pomegranate juice', and which aromatic profile could be successful in improving the acceptance of this healthy product. Copyright © 2011 John Wiley & Sons, Ltd.

Keywords: volatile; *Punica granatum* L.; SPME; GC–MS; flavour; sensory

Introduction

Pomegranate (*Punica granatum* L.) is a fruit becoming more popular because of its healthy properties (anti-atherogenic, anti-oxidant, antihypertensive, etc.), which have been widely shown in previous studies.[1–4] These healthy properties come from the high anti-oxidant activity of the fruit and are directly related with its phenolic compounds content.[5–10]

The phenolic content of pomegranate has been reported in fruits from different countries[9,10] and in several pomegranate juices,[5,8] demonstrating that anti-oxidant activity of the fruit remains almost intact from fruit to juice. The high anti-oxidant activity of pomegranate juices is mainly caused by the punicalagins and ellagic acid derivates, compounds located mainly in the rind of the fruit.[5] Some methods for extracting the juice, which rub the internal part of the pomegranate rind, may contribute to the extraction of these compounds.

Pomegranate juice can be found as 'juice from direct extract', 'juice from concentrate', 'juice concentrate' and 'juice from concentrate with natural flavours'. Product appearance varies from red to brown colour and sometimes with turbidity and some residue present. These variations are conditioned mainly for the different types of processing to elaborate the final juice. The juice can be concentrated to ensure longer storage life and easier transportation, or subjected to a clarification process, reducing the amount of phenolic substances. During concentration, the colour of the juice changes and some volatile compounds are lost.[11] During clarification, some sensory properties of the juice will improve (e.g. colour, turbidity, overall appearance and bitterness),[12] but the healthy benefits of the juice will be reduced when particles and phenolic substances are removed.

One sensory study found large differences in sensory characteristics among 33 commercial juices; differences mainly found in the aromatic profiles of the products and that could be the result of processing, pomegranate variety or other issues.[13] These authors clustered products into five groups of juices, based on overarching sensory properties: dark-fruity; grape; berry; fermented or musty/earthy; and beet attributes.

Although several studies have been conducted on pomegranate juices, none were found that provided information about volatile composition or differences in the instrumental aroma profiles of the juices. Researching these end-products is of great interest, because they are the products which people will consume and which have a direct effect on consumers' acceptance. Although the aromatic composition of the pomegranate or pomegranate products has not yet been well described, many products can be found in the market labelled 'with pomegranate aroma', such as softeners, hand soap, aromatic candles, flavoured

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water, etc. The extraction method mainly chosen for studying the aroma profile in fruits and derivates is solid phase microextraction (SPME). It is primarily a non-quantitative extraction technique, but the heating of the sample is low and the aroma profile obtained is closer to real than with other extraction techniques, such as simultaneous distillation–extraction or hydrodistillation.[14]

The objective of this study was to describe sensory and instrumental aroma characteristics of selected commercial pomegranate juices and to determine their similarity to fresh pomegranate juice. This information will be useful for companies, consumers and researchers to provide a general idea of the aromatic composition of pomegranate products, and not only to improve the aroma of the commercial juices but also to provide ideas in developing fragrances which could be added to cosmetic and other products.

Experimental

Samples

Fourteen pomegranate juice samples were used for the study, 13 commercial juices and one fresh-squeezed juice (F) prepared from fresh pomegranate arils (Wonderful Cultivar, USA). All the commercial juices were produced in the USA and were available in Manhattan, KS, USA. Two of the samples were 'juice from direct extract' (DE), five were 'juice from concentrate' (C), one 'juice concentrate' (included in the C group) and five were 'juice from concentrate with natural flavourings added' (AD) (Table 1). All these products were available in local grocery stores, supermarkets and speciality stores in the area. At least three bottles of each commercial sample were purchased (around 3 litres of each juice).

F juice was prepared by manually extracting the arils from the pomegranate and squeezing them with a kitchen juicer. Three different juices were prepared, one each from three different pomegranates. All nine fruits were purchased during the same week and from the same grocery store. The arils were used whole, without removing the seed or the carpellar membranes, because they would be separated later by the juicer while extracting the juice. No additives or preservatives were added, and no heat treatment was done.

All of the samples were assigned random three-digit codes. The commercial products were stored following the instructions on the packaging and studied before the indicated expiry date. The F juice was studied on the same day it was prepared. For sensory analysis, the concentrates were diluted according to the directions on the packaging.

Analysis of Volatile Composition

Extraction procedure for volatile aroma compounds. Each sample (2 ml) was hermetically placed in a 10 ml vial with a polypropylene hole cap PTFE/silicone septum. The vials were equilibrated for 10 min at 40°C in the autosampler (Pal System, Model CombiPal, CTC Analytics, Switzerland). After this equilibration time, a DVB/CAR/PDMS fibre (50/30 μm thickness) was exposed to the sample headspace for 30 min at 40°C.[15] After sampling, desorption of the analytes from the fibre coating was carried out in the injection port of the gas chromatograph at 250°C for 5 min in splitless mode.

Three replications of each sample juice were done for the instrumental aromatic compounds study. Each replication was from a different bottle of the corresponding commercial sample. Regarding F juice, each replicate was from one of the three prepared juices.

Chromatographic analyses. The isolation, identification and semi-quantification of the volatile compounds were performed on a gas chromatograph (Varian GC CP3800; Varian, Walnut Creek, CA, USA) coupled with a Varian mass spectrometer (Saturn 2200) and operated with MS

Table 1. Characteristics of commercial juices used for the study (indicated in the product)

Juice code	Characteristics	Considered in this study
943	Fresh squeezed pomegranate juice	DE
279	Fresh pressed juice from whole ripe certificated pomegranates	DE
197	Pomegranate juice from concentrate	C
981	Pomegranate juice concentrate	C
488	Pomegranate juice from concentrate	C
555	Pomegranate juice from concentrate	C
225	Pomegranate juice from concentrate, purified water, potassium benzoate, potassium sorbate	C
655	Pomegranate juice from concentrate, purified water, potassium benzoate, potassium sorbate	C
143	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate) with natural flavours	AD
846	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate) with natural flavours	AD
566	Pomegranate juice from concentrate with natural flavours	AD
328	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate) with natural flavors. Flash pasteurized	AD
403	Pomegranate juice from concentrate, natural flavors, grape seed extract. Gently pasteurized	AD

Workstation software. The GC–MS system was equipped with a VF-5MS column (5% phenyl, 95% dimethylpolysiloxane; Varian; 30 m × 0.25 mm i.d., 1.0 µm film thickness). The starting temperature of the column was 40°C, which was held for 10 min, then increased 8°C/min to 180°C, and finally increased at 10°C/min to 280°C, where was held for 10 minutes. The constant column flow was 1 ml/min, using helium as the carrier gas.

Most of the compounds were identified using two different analytical methods: (a) Kováts indices; (b) mass spectra (authentic chemicals and Wiley spectral library collection).

Semi-quantification of volatile aroma compounds. To semi-quantify the volatile compounds, 1,2-dimethoxybenzene was used as internal standard (final concentration in the sample of 4 mg/kg). The internal standard facilitates the comparison of compounds among samples. Headspace composition is not an accurate representation of the amount of each compound in the sample. All results presented in the discussion were relative to an internal standard; chemical compounds or chemical groups were not compared from a quantitative (or semi-quantitative) point of view. The MS detector was used in scan mode during the study, which is not valid for absolute quantification of volatile compounds.[16]

Sensory Evaluation with a Trained Panel

Panellists. Five highly trained panellists from the Sensory Analysis Center (Manhattan, KS, USA) participated in this study. Each of the panellists had more than 1000 h of testing experience with a variety of food products. For the current study, the panellists received further orientation on fresh and processed pomegranates.

Sample serving. The juices were shaken and poured into odour-free, disposable 90 ml covered plastic cups (Sweetheart Cup Co. Inc., Owings Mills, MD, USA) for the evaluation. All of the samples were served at room temperature within 30 min before the testing. Each panellist received 60 ml of each product for evaluation. Additional samples were available if needed.

Sample evaluation procedure. Twelve 1.5 h sessions were held for the sample evaluations. One or two samples were evaluated each day. All the samples were coded with three-digit random numbers, and the order in which the products were evaluated was randomized. The descriptive attributes used for this study are shown in Table 2 (definitions for each attribute can be found in Koppel and Chambers).[13]

A modified flavour profile method which uses a numerical scale, where 0 represents none and 15 extremely strong, with 0.5 increments, was used.[17,18] The testing room was at 21 ± 1°C and 55 ± 5% RH; the illumination was a combination of natural and non-natural (fluorescent) light.

Data Analyses

Partial least squares regression (PLSR) map was conducted using Unscrambler version 9.7 (Camo Software, Oslo, Norway).

Results and Discussion

Sensory Analysis

Seventeen aroma attributes were found in the 13 commercial samples and the F juice (Table 2). F juice (sample 458) was characterized by having a high fruity aroma with berry, cranberry, fruity dark and floral notes. In addition, some musty/earthy notes and a moderate overall sweetness were detected. DE juices had some differences and were characterized by: fruity, cranberry, grape, musty/earthy and wine-like notes. In general, all these aromatic attributes were present in the AD juices, but not all of

Table 2. Sensory aroma profile of the juices used for the study: 15 point numerical scale with 0.5 increments

Juice type	Sample code	Sensory attribute																
		Fruity	Apple	Fruity-dark	Berry	Cherry	Cranberry	Grape	Floral	Fermented	Candy-like	Beet	Molasses	Musty/ Earthy	Vinegar	Sweet overall	Wine-like	Woody
F	458	9.0	-	2.0	4.5	-	2.0	-	3.0	-	-	-	-	2.0	-	6.5	-	-
DE	943	3.0	-	-	2.5	-	5.5	5.5	-	2.0	-	-	-	2.0	-	3.5	3.0	-
DE	279	2.5	-	-	-	-	4.5	6.0	-	-	-	3.0	-	2.5	-	4.5	4.5	-
C	197	-	-	9.0	-	-	-	-	-	-	-	-	6.5	3.5	-	4.5	-	4.0
C	981	4.0	-	-	-	-	-	5.5	-	-	8.0	-	-	-	-	8.0	-	-
C	488	-	-	3.0	-	-	-	-	-	-	-	-	-	2.5	-	1.5	-	-
C	555	-	-	7.0	-	-	-	-	-	-	-	-	-	2.5	-	4.0	-	-
C	225	3.5	2.0	-	3.0	-	-	-	-	4.5	-	-	-	3.5	3.5	2.5	-	-
C	655	-	-	5.0	-	-	-	2.5	-	4.5	-	-	-	3.5	5.0	3.5	-	-
AD	143	2.5	-	-	5.0	-	7.0	3.0	-	-	-	-	-	-	-	3.0	2.5	-
AD	846	6.5	5.5	-	5.5	4.0	5.0	-	3.5	4.5	-	-	-	3.5	-	4.5	-	-
AD	566	2.0	-	-	-	-	3.5	7.0	1.5	2.5	-	1.5	-	-	-	4.0	5.0	-
AD	328	-	-	-	4.5	-	6.5	4.5	-	-	-	2.0	-	2.0	-	4.0	2.0	-
AD	403	8.5	-	3.0	4.5	-	7.0	3.0	-	-	-	-	-	2.5	-	4.5	-	-

NOTE: Rows without numeric score indicate that this attribute was not present in that specific sample.

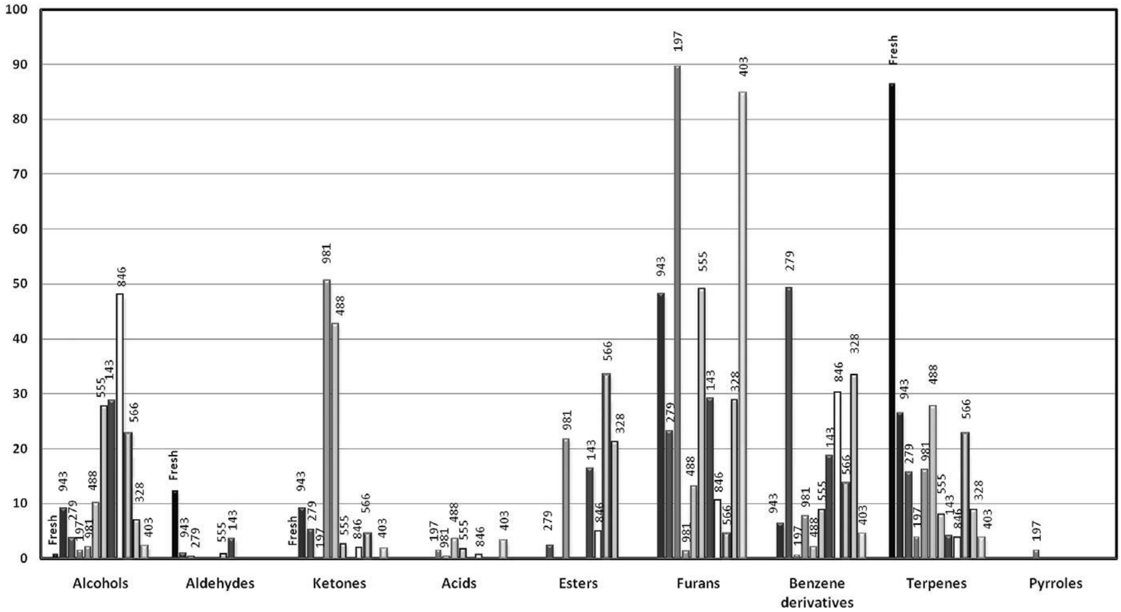

Figure 1. Percentages of volatile groups, relative to the internal standard, present in the headspace of juice samples. Each bar corresponds to a different sample. Fresh, F juice; samples 943 and 279, DE juices; samples 197, 981, 488 and 555, C juices; samples 143, 846, 566, 328 and 403, AD juices

them in the C juices. Cranberry and wine-like notes were absent in all the C juices, and new aromatic notes were detected by the panellists, e.g. fruity dark (samples 197, 488, 555 and 655), candy-like (sample 981), molasses (sample 197), vinegar (samples 225 and 655) and woody (sample 197). Samples 225 and 655 were the only ones with potassium sorbate and potassium benzoate, which might be the origin of the vinegar note.

The AD juices had all the same attributes present that were found in the F and DE juices, including the cranberry and wine-like notes. Because of the added flavourings in the AD samples, new aromatic notes (apple and cherry, sample 846), which were absent in the other juices, were detected by the panellists.

Instrumental Volatile Compounds

Eighty-three aromatic compounds were found in the pomegranate juice samples. Table 3 shows the presence or absence of each of the compounds, according to their chemical families. Alcohols, aldehydes, ketones, esters, furans, benzene derivatives and terpenes were the main aromatic groups but large differences were found, depending from the juice type.

In samples 225 and 655, high amounts of sorbic acid and benzoic acid were found, obviously from the potassium sorbate and potassium benzoate added as preservatives. The presence of these preservatives in high concentrations made it completely impossible to conduct proper instrumental analyses of these juices (40% of the chromatogram time scale was occupied by these two peaks, hiding the presence of other compounds). Therefore, the data presented in Table 4 for these samples is tentative only and the percentages over the total are not shown in Figure 1. Neither of samples 225 and 655 was studied in partial least square regression (PLS2), due to this lack of instrumental data.

As shown in Table 4, the total amounts of volatile compounds were different in the headspace of each sample. Using F juice as the reference, eight of the juices had lower amounts of volatile compounds than this juice and five had higher amounts, but these differences did not seem to be related to the juice type.

Sample 981 was noted for the high amount of total aromatic compounds in its headspace (83.6 mg/kg) when compared with the other samples. This sample was a C juice which could be consumed in the concentrated form or diluted with water as a juice (following the instructions of the label). Despite this high concentration of volatiles, when diluted in its juice form, the sample was characterized by having only four aromatic notes: candy-like, fruity, grape and sweet overall (Table 2). The candy-like attribute was exclusive for this sample, and the sweet overall note was much higher than in any other sample, possibly coming from the high concentration procedure to which the sample was subjected. As can be seen in Figure 1, sample 981 had a significant amount of ketones, represented mainly by β-ionone and a γ-undecalactone. β-Ionone is a ketone typical in berries and its descriptors are related with these fruits, being a key odourant in raspberry aroma.[18,20]. Regarding the γ-undecalactone, it is known that because the aroma of lactones is pleasant, these substances are used for aromatization of food.[21] This may be the case in this sample, because of the higher amounts of the compound compared with the other juices (note that the juice was not indicated as ‘with flavourings added’ on the label of the product, so it was included in the C group during this study). The presence of higher amounts of esters in sample 981 when compared with the others seemed to confirm the presence of some additional flavourings. These compounds were not present in the F or C juices, but only in AD samples. Esters are important aromatic compounds for fruits, synthesized only by intact cells

Table 3. Aromatic volatile compounds found in the juice samples

Code*	Compound	KI (Lit.)	KI (Exp.)	Sample (mg/kg)													
				Fresh	Direct extract		From concentrate						From concentrate + added flavourings				
				458	943	279	197	981	488	555	225	655	143	846	566	328	403
Alcohols																	
A1	Ethanethiol	514	**	–	–	–	–	–	–	–	–	–	0.27	–	–	–	0.10
A2	2-Methyl-3-buten-2-ol	**	**	–	–	–	0.12	–	–	0.03	–	–	0.04	–	–	–	0.07
A3	1-Pentanol	765	747	–	–	–	–	0.05	–	–	–	–	0.01	–	–	–	–
A4	2,3-Butanediol	806**	754	–	–	–	–	0.57	–	–	–	–	–	–	–	–	–
A5	2-Pentyn-1-ol	**	767	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–
A6	3-Methyl-2-buten-1-ol	772	781	–	–	–	0.03	–	–	–	–	–	–	–	–	–	0.02
A7	*Z*-3-Hexen-1-ol	858	861	0.02	–	–	–	0.80	–	0.01	–	–	–	0.15	–	0.08	–
A8	*E*-3-Hexen-1-ol	860	859	–	–	–	–	–	–	0.12	–	–	–	4.09	–	–	–
A9	4-Methyl-1-pentanol	875**	851	–	–	–	–	0.33	–	0.11	–	–	–	–	–	–	–
A10	2-Heptanol	911	900	–	–	0.14	0.05	–	–	–	–	–	–	0.11	–	–	0.02
A11	1-Heptanol	970	971	–	–	–	–	–	–	–	–	–	0.06	–	–	–	–
A12	1-Octen-3-ol	979	981	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
A13	3-Octanol	992	998	0.02	0.03	0.03	–	–	0.03	0.04	–	–	0.03	0.05	0.04	0.02	–
A14	2-Ethyl-1-hexanol	1032	1031	–	0.06	0.02	0.07	–	0.25	–	–	–	0.22	0.03	0.01	0.01	–
Aldehydes																	
A15	Hexanal	802	802	0.13	–	0.02	0.02	–	–	–	–	–	0.04	–	–	–	–
A16	*E*-2-Hexenal	865	861	–	–	–	–	–	–	–	–	–	0.04	–	–	–	–
A17	Heptanal	896	904	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
A18	Octanal	1001	1007	0.04	0.01	–	–	–	–	–	–	–	–	–	–	–	–
A19	Nonanal	1102	1111	0.38	–	–	–	–	–	–	–	–	–	–	–	–	–
Ketones																	
A20	3-Hexen-2-one	**	760	–	–	–	–	–	0.01	–	–	–	–	–	–	–	–
A21	4-Methyl-3-penten-2-one	800	799	–	–	–	–	–	0.93	–	–	–	–	–	–	–	–
A22	4-Hydroxy-4-methyl-2-pentanone	840	847	–	–	–	–	–	0.21	–	–	–	–	–	–	–	–
A23	6-Methyl-5-hepten-2-one	986	987	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
A24	3-Octanone	990	988	–	0.01	–	–	–	–	0.01	–	–	–	0.04	0.01	–	–
A25	α-Isophorone	1122**	1142	–	–	–	–	–	–	0.02	–	–	–	–	–	–	–
A26	β-Damascenone	1375**	1402	–	0.09	0.11	0.05	–	–	–	–	–	–	0.14	–	–	0.15
A27	β-Ionone	1493	1501	–	–	–	–	0.59	–	–	–	–	–	–	–	–	–
A28	γ-Undecalactone	1547**	1588	–	–	0.15	–	41.7	0.02	–	1.82	–	–	–	–	–	–
Acids																	
A29	Acetic acid	602	**	–	–	–	0.06	0.10	0.10	0.02	0.29	–	–	–	–	–	0.29
A30	2-Methyl butanoic acid	867**	844	–	–	–	0.22	0.21	–	–	–	–	–	0.06	–	–	–
Esters																	
A31	Ethyl acetate	610	**	–	–	–	–	1.98	–	–	–	–	–	–	–	–	–
A32	Butanoic acid ethyl ester	798	802	–	–	–	–	0.01	–	–	–	–	0.08	–	0.02	0.16	–
A33	Acetic acid butyl ester	816	817	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–
A34	2-Methyl butanoic acid ethyl ester	849	853	–	–	0.11	–	0.52	–	–	–	–	0.26	0.27	0.05	0.11	–
A35	3-Methyl-1-butanol acetate	878	879	–	–	–	–	1.65	–	–	–	–	0.02	–	–	0.06	–
A36	Hexanoic acid ethyl ester	999	997	–	–	–	–	0.06	–	–	–	–	–	–	–	–	–
A37	3-Hexen-1-ol acetate	1011	1004	–	–	–	–	0.11	–	–	–	–	–	0.20	–	–	–
A38	Acetic acid hexyl ester	1015	1011	–	–	–	–	8.72	–	–	0.12	–	–	–	–	–	–
A39	*Z*-nerol acetate	1366	1368	–	–	–	–	1.52	–	–	–	–	–	–	–	–	–
A40	*E*-nerol acetate	1381	1382	–	–	–	–	3.58	–	–	–	–	–	–	–	–	–

Table 3. *Continued.*

Code*	Compound	KI (Lit.)	KI (Exp.)	Sample (mg/kg) Fresh	Direct extract		From concentrate						From concentrate + added flavourings				
				458	943	279	197	981	488	555	225	655	143	846	566	328	403
Furans																	
A41	Furfural	835	839	–	0.44	1.07	7.54	1.11	0.33	0.52	0.04	0.90	0.61	0.79	0.01	0.37	5.87
A42	2-Furanmethanol	857	858	–	–	–	0.05	–	–	–	–	–	–	–	–	–	–
A43	1-(2-Furanyl)-ethanone	911	915	–	0.04	0.03	0.51	0.07	0.03	0.03	–	–	0.03	0.11	–	0.08	0.32
A44	2-Furaldehyde	957	968	–	–	–	2.64	–	–	–	–	–	–	–	–	–	0.58
A45	Furyl ethyl ketone	1019	1015	–	–	–	0.11	–	–	–	–	–	–	–	–	–	–
A46	Furfuryl alcohol	1081	1082	–	–	0.05	–	–	–	–	–	–	–	0.08	–	–	0.17
A47	5-Hydroxymethylfurfural	1241**	1214	–	0.05	–	3.89	–	–	–	–	–	–	–	–	–	0.75
Benzene derivatives																	
A48	Benzaldehyde	936**	974	–	0.03	2.44	0.12	6.46	0.04	0.10	0.42	0.69	0.22	2.79	0.03	0.34	0.18
A49	Phenol	980	980	–	0.04	–	–	–	–	–	–	0.20	–	–	–	–	–
A50	Benzyl alcohol	1043	1046	–	–	–	–	–	–	–	–	–	0.19	–	–	0.18	–
A51	Eugenol	1348**	1376	–	–	–	–	–	–	–	–	–	–	–	–	–	0.23
A52	Methyleugenol	1395	1407	–	–	–	–	–	0.03	–	–	–	–	–	–	–	–
Terpenes																	
A53	α-Pinene	939	944	0.03	–	–	–	–	–	–	–	–	–	–	–	–	–
A54	β-Pinene	980	992	0.22	–	–	–	1.49	–	–	–	–	–	–	–	–	–
A55	3-Carene	1020	1022	–	–	–	–	0.14	–	–	–	–	–	–	–	–	–
A56	Eucalyptol	1031	1026	–	–	–	0.03	–	–	–	–	–	0.03	0.23	–	–	0.05
A57	4-Carene	1014	1030	–	–	–	–	0.23	–	–	–	–	–	–	–	–	–
A58	β-Cymene	1021	1037	–	–	–	0.06	–	–	–	–	–	–	–	–	–	–
A59	*Z*-Ocimene	1041	1039	–	–	–	–	0.40	–	–	–	–	–	–	–	–	–
A60	Limonene	1031	1043	0.34	–	–	0.12	–	0.35	–	–	–	–	–	–	–	–
A61	α-Phellandrene	1012**	1046	0.08	–	–	–	–	–	–	–	–	–	–	–	–	–
A62	*E*-Ocimene	1052	1051	–	–	–	–	0.56	–	–	–	–	–	–	–	–	–
A63	γ-Terpinene	1066	1070	–	–	–	–	0.25	–	–	–	–	–	–	–	–	–
A64	Terpinolene	1088	1100	–	–	–	–	1.32	0.04	–	–	–	–	–	–	–	–
A65	Linalool	1098	1103	–	–	0.08	–	–	–	–	–	–	–	–	0.03	–	–
A66	β-Terpineol	1188**	1167	–	–	–	–	0.61	0.04	–	–	–	–	–	–	–	–
A67	4-Terpineol	1179**	1201	0.19	–	0.20	–	–	–	–	–	–	–	–	–	–	–
A68	*p*-Cymen-8-ol	1189	1201	–	0.15	–	–	–	–	–	–	–	–	–	–	–	–
A69	α-Terpineol	1189	1207	0.32	0.03	0.49	0.37	4.46	0.33	0.09	–	–	0.06	0.13	0.02	0.14	0.28
A70	*Z*-Geraniol	1228	1226	–	–	–	–	0.50	–	–	–	–	–	–	–	–	–
A71	*Z*-Carveol	1230	1234	–	0.12	–	–	–	–	–	–	–	–	–	–	–	–
A72	Thymol	1290**	1245	–	–	–	0.08	–	–	–	–	–	–	–	–	–	–
A73	Bergamotene	1435**	1391	0.16	–	–	–	–	–	–	–	–	–	–	–	–	–
A74	Copaene	1380**	1406	–	–	–	–	0.22	–	–	–	–	–	–	–	–	–
A75	2-Norpinene	1436	1430	0.16	–	–	–	–	–	–	–	–	–	–	–	–	–
A76	α-Farnesene	1487**	1450	1.09	–	–	–	–	–	–	–	–	–	–	–	–	–
A77	β-Caryophyllene	1418**	1454	0.74	–	–	–	2.12	–	–	–	–	–	–	–	–	–
A78	Cedrene	**	1466	0.13	–	–	–	–	–	–	–	–	–	–	–	–	–
A79	Bisabolene	1522	1520	0.31	–	–	–	–	–	–	–	–	–	–	–	–	–
A80	Valencene	1495**	1523	–	–	–	–	0.53	–	–	–	–	–	–	–	–	–
A81	γ-Muurolene	1480**	1538	–	–	–	–	0.63	–	–	–	–	–	–	–	–	–
A82	Sesquiphellandrene	1523	1537	0.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Pyrroles																	
A83	2-Acetylpyrrole	1072	1071	–	–	–	0.27	–	–	–	–	–	–	–	–	–	–

* Code used to simplify Figures 2 and 3.
** Tentatively identified: only mass spectral data. Values are the mean of three replications.

Table 4. Aromatic volatile groups found in the juice samples

Chemical group	Sample (mg/kg)													
	Fresh	Direct extract				From concentrate				From concentrate + added flavourings				
	458	943	279	197	981	488	555	225*	655*	143	846	566	328	403
Alcohols	0.04	0.10	0.19	0.27	1.75	0.28	0.31	n.d.	n.d.	0.63	4.44	0.05	0.11	0.20
Aldehydes	0.56	0.01	0.02	0.02	n.d.	n.d.	0.01	n.d.	n.d.	0.08	n.d.	n.d.	n.d.	n.d.
Ketones	0.01	0.10	0.26	0.05	42.3	1.17	0.03	1.82	n.d.	n.d.	0.18	0.01	n.d.	0.15
Acids	n.d.	n.d.	n.d.	0.27	0.31	0.10	0.02	0.09	n.d.	n.d.	0.06	n.d	n.d.	0.29
Esters	n.d.	n.d.	0.12	n.d.	18.2	n.d.	n.d.	0.12	n.d.	0.36	0.46	0.07	0.33	n.d.
Furans	n.d.	0.53	1.15	14.7	1.18	0.36	0.55	0.04	0.90	0.64	0.98	0.01	0.45	7.69
Benzene derivatives	n.d.	0.07	2.44	0.12	6.46	0.07	0.10	0.42	0.89	0.41	2.79	0.03	0.52	0.41
Terpenes	3.89	0.29	0.78	0.67	13.5	0.76	0.09	n.d.	n.d.	0.09	0.36	0.05	0.14	0.34
Pyrroles	n.d.	n.d.	n.d.	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total	4.50	1.10	4.96	16.4	83.6	2.74	1.12	2.49	1.79	2.20	9.26	0.22	1.56	9.09

* Samples 225 and 655 were not comparable with the other samples, due the presence of high amounts of conservatives, which prevented a proper analysis of the full chromatogram.

during the β-oxidation of fatty acids or from amino acid metabolism. Generally, when the fruits are homogenized, the esters are rapidly hydrolysed by the hydrolase enzymes present, and the fruit aroma flattens.[21] AD samples had esters in their volatile profile. These could be the compounds responsible for the apple, beet, cherry, floral and fruity notes.

Sample 846 (belonging to the AD group) had the highest fruity aromatic note, highlighted by the presence of more alcohols than the other juices. The main components in this sample were *Z*- and *E*-3-hexen-1-ol, present in the F juice and in other fruits such as berries.[19,20] The high concentration of these alcohols in some samples compared with the other samples indicated that this might be one of the compounds in the added flavourings of AD samples.

Benzene derivatives were present in all the juices except the F juice. These compounds come from the degradation of lignin and phenolic acids and their aromatic notes are variable, depending on the compound being formed, usually either vanilla, woody, smokey or spicy. Benzaldehyde was the main compound from this family, being present in all the commercial juices (DE, C and AD). Almond, cherry and sweet are the descriptors for this compound, which is normally found in almonds and other nuts and is common in 'artificial' cherry flavours.[22,23] Although this compound was absent in the F sample, the small amount of benzaldehyde in some commercial juices, and its presence in the C juices, indicated that this might not be an added flavouring or that small amounts of this compound might be enough to produce a heightened fruit flavour in the juices (its odour threshold in water is only 0.35 mg/l).[24]

The two aromatic groups which seemed to represent a huge difference between commercial and F juice were terpenes and furans. Terpenes seemed to be the predominant group in the F juice, which had no furans. Commercial juices had furans, and terpenes were never the main group. Some terpenes with hydroxy groups are naturally present in fruit juice, at least in part as glycosides. These terpene glycosides hydrolyse, either enzymatically (β-glucosidase) or because of the low pH of the juices. The latter process is strongly accelerated by heat treatments,[21] changing the terpene profile in the juices.

Furan compounds, which were present in the commercial samples and not in the F sample, are commonly associated with heated products and have been related previously with Maillard reactions and caramel-like aromas, coming from the toasting process in some nuts, such as almonds.[22,23] The processing in the commercial juices implicates some pasteurization (e.g. samples 328 and 403) or other heating methodology to preserve the juice, so furan compound development is expected (mainly furfural). The presence of the molasses attribute in the sensory analysis of sample 197 (C) might be due to the presence of these compounds in its volatile composition. This attribute was not found in sample 403 (AD), which also was characterized by large amounts of furans and furfural, but the presence of added flavourings with low odour thresholds in the sample could hide this aromatic note in favour of the fruity or cranberry notes that highlighted in the juice.

Relationship between Sensory and Instrumental Aromas

When taking into account the first two dimensions of the PLSR biplot (PLS1 and PLS2), 48% variation in the instrumental data explained only 37% of variation in the sensory data (Figure 2). Despite the low variation explained, two different groups could

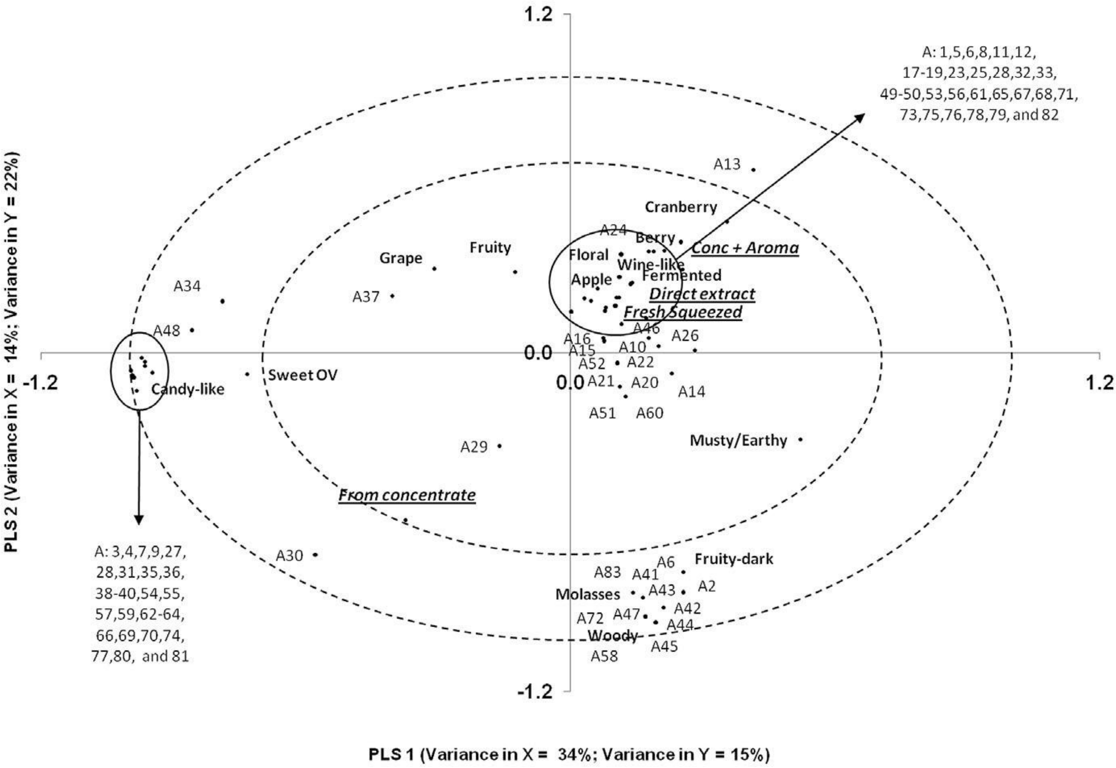

Figure 2. PLS regression map showing the relationship between instrumental data correlated with sensory data in all the juices studied. Fresh-squeezed, F juice; direct extract, DE juices; from concentrate, C juices; Conc + aroma, AD juices. Sensory parameters were characterized as indicated in Table 2; instrumental data, aromas (A1–A83, codes indicated in Table 3)

be differentiated in this figure, C juices on the one hand and F, DE and AD juices on the other hand. The presence of some compounds originated during the concentration stage of these samples might hide and/or modify some aromatic attributes expected in the pomegranate juices. In addition, some aromatic compounds could have been lost during the concentration step. Fruit juice concentrates are elaborated using evaporation, freezing or a process involving high-pressure filtration.[19] Concentration by evaporation is the preferred industrial process, but this process leads to losses in aromatic compounds if it is not combined with an appropriate aroma recovery step. One example of this on C juice could be sample 982, in which the candy-like or overall sweet attribute was so intense that it hid the fruity and cranberry notes that the terpenes present in the sample should provide to the juice.

Although there was a low variation explained, some general tendencies seemed to appear in the PLS study (Figure 2): six of the seven furan compounds (A41–A47) seemed to be related to the woody, molasses and fruity-dark notes. These attributes are typical of processed foods. On the other side of the graph, terpenes (A53–A82) and esters (A31–A40) were associated with candy-like and sweet overall notes.

A second PLS regression was done to determine the differences among the F, DE and AD juices. The results for the first two dimensions of the PLSR biplot are shown in Figure 3. Once the concentrate juices were eliminated from the PLS study, 48% of variation in the instrumental data for the first two dimensions of the PLSR biplot (PLS1 and PLS2) explained 61% of the variation in the sensory data, and 33% of variation in the instrumental data in the second two dimensions of the PLSR biplot (PLS3 and PLS4) explained 27% of the variation in the sensory data (a total of 81% of variation in the instrumental data explained 88% of the variation in the sensory results).

While juice from fresh squeezed arils was characterized by having high fruity-dark, floral, fruity and sweet overall notes, commercial juices had more cranberry, wine-like and grape notes. Fresh-squeezed juice was characterized by the presence of aldehydes (A15, 17–19) and terpenes (A54, 56, 61, 65, 68, 75–79 and 82), while the commercial juices had a combination of compounds which included mainly alcohols (A1–14) and some esters and furans (A32–37, and A41, 44 and 47, respectively). No experiments were done to test the relationship between the identified compounds and the sensory attributes, but these tentative results seemed to show that aldehydes and terpenes contributed to the fruity, sweet overall and fruity dark notes of the F juice. Also, the combination of alcohols, esters and terpenes seemed to contribute to the grape and wine-like notes in the AD juices. With the aim of confirming these statistical results, a real quantification of the compounds may be done. Once the compounds have been quantified, sensory analysis would determine the corre-

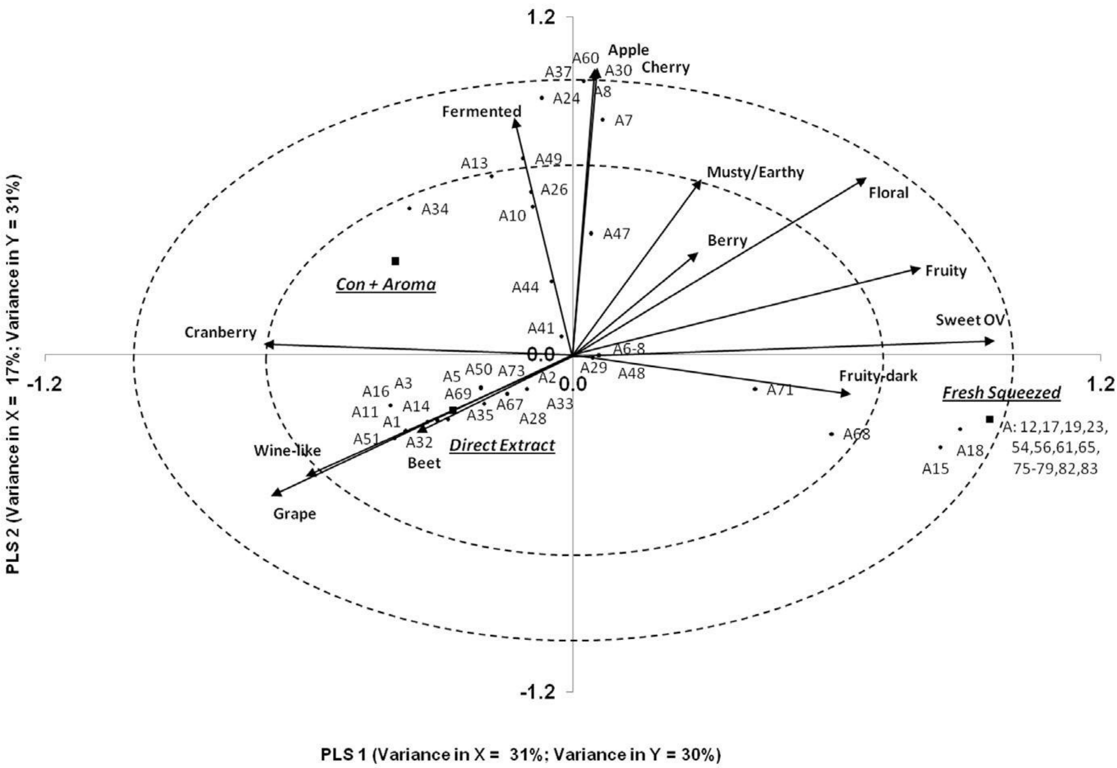

Figure 3. PLS regression map showing the relationship between instrumental data correlated with sensory data in fresh squeezed juice, juices from direct extract and juices from concentrate with added flavourings. Fresh-squeezed, F juice; direct extract, DE juices; Conc + aroma, AD juices. Sensory parameters were characterized as indicated in Table 2; instrumental data, aromas (A1–A83, codes indicated in Table 3)

sponding descriptors associated with each one of the compounds or groups of compounds (using a non-aromatic juice, with the same characteristics as the pomegranate juice, as a base to spike the compounds).

Conclusions

Up to 83 aromatic compounds were found in the 14 pomegranate juices. All juices had different instrumental and sensory aromatic profiles. The main differences in chemical composition between fresh-squeezed and commercial juices were the percentages of terpenes and furans. Fresh-squeezed juice was mainly characterized by the presence of terpenes and aldehydes, while furans were important contributors in the commercial juice aromas. Different processing methodologies to manufacture the juice can change the aromatic profile of the fresh juice, particularly in juices from concentrate, as shown in the PLS study. Seventeen different sensory attributes were found in these pomegranate juices, including fruity, floral or musty notes. Each one of the samples was characterized by the presence of only some of the attributes (three to nine different aromatic notes, depending of the sample). Juice from fresh-squeezed arils was characterized by having more, floral, fruity and sweet OV notes, compared with commercial juices from direct extract and with added flavourings, which had more cranberry, wine-like and grape notes. Juices from concentrate were highlighted by fruity dark notes and the presence (in some samples) of other notes typical in processed foods (e.g. molasses, candy-like). Methodologies to improve pomegranate juice extraction or preservation, or even artificial aromas of pomegranate, should be developed with the aim of creating higher quality products which can increase the consumption of pomegranate juice and allow consumers to take advantage of its health-promoting properties.

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Article III

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POSSIBILITY FOR A STRAWBERRY JAM SENSORY STANDARD

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ABSTRACT

Sensory and instrumental characteristics of 25 commercial strawberry jam samples manufactured in 11 countries were compared to determine whether the development of a sensory or origin standard for strawberry jams was practical. Appearance, texture and flavor attributes were evaluated by sensory analysis. Color, hardness, sugar and acid profile, pH, dry weight and Brix of the samples were measured using instrumental means. The sweet attribute was correlated with total sugars (0.88), glucose (0.68), sucrose content (0.71), Brix (0.89) and dry weight of the samples (0.91). Sensory properties indicated three clusters of jams: (1) sweet, red-colored jams holding a high-fruit content; (2) jams containing artificial aromas and a granular structure; and (3) brown-colored jams that were somewhat bitter, sour and astringent. Those clusters were independent of country of origin, thus a Protected Designation of Origin standard does not seem appropriate. However, a sensory standard based on color, sweetness and natural strawberry identity appears possible.

PRACTICAL APPLICATIONS

Strawberry flavoring and strawberry jams are used widely in various food products including pastries, dairy products and confectionery. Product developers, technologists and scientists in the food industry can benefit if a standard for the strawberry jam product category can be developed that are not dependent on country of origin.

INTRODUCTION

Strawberry is one of the most popular flavors within a range of food products, including jams and bakery or other categories that use jam as fillings, toppings or as an ingredient. Thus, there is a strong need for quality and authenticity determinations. Several studies, captured by Fügel *et al.* (2005), have been conducted on jam and fruit puree authenticity and quality measurements. Quality can be characterized by describing the organic acids or sugars profile. Certain organic acids and sugars present in fruit preserves can act as indicators of authentic composition. For example, Coppola and Starr (1988) suggested quinic acid in cranberries and tartaric acid in grapes should be checked when the quality of the product is under question. Similarly, for kiwi puree, quinic acid and ascorbic acid are the compounds to be analyzed (Castaldo *et al.* 1992). However, while chemical composition may indicate a true source of materials, they do not describe the resulting sensory quality of the product.

Recently, European countries have used "Protected Designation of Origin" (PDO) standards to indicate quality (Eur-Lex, EC 510/2006). However, Oupadissakoon *et al.* (2009) found that the sensory properties of ultra-high-temperature milk were not dependent on country, but were more likely the result of processing. The effect of cooking of fruit purees influenced the viscosity (Maceireas *et al.* 2007). Grigelmo-Miguel and Martin-Belloso (1999) showed that adding dietary fiber caused jams to be darker in color. Those studies indicate the importance of selecting ingredient and processing conditions to obtain an end-product with needed sensory properties. Developing a sensory standard for manufacturers of fruit preparations may help them upgrade and measure quality of their products.

There are several studies on lexicon developments that use the whole category of products and provide the technologists, product developers and food scientists with useful information on sensory characteristics. Some studies have characterized a range of foods where the processing degree is different. For example, Hongsoongnern and Chambers (2008) developed a lexicon for fresh and processed tomato products and characterized the sensory and texture properties of a wide range of those products. Civille *et al.* (2010) studied almond varieties, Koppel and Chambers (2010) studied pomegranate juices, and Talavera-Bianchi *et al.* (2010) studied green leafy vegetables to develop the vocabulary necessary for descriptive sensory analysis of those products, but no lexicons for strawberry jam were found.

Sensory and instrumental measurements have been used in studies describing several similar products or in a single-product category. Tarrega and Costell (2007) studied the color and consistency of commercial vanilla dairy dessert samples using sensory and instrumental measurements. These sensory ranking tests were used to evaluate variations in color and consistency of the samples. In a separate study, grapes from five ripening stages and growing in three locations were studied by Le Moigne *et al.* (2008). The thorough descriptive vocabulary included referenced attributes for skin, berry and seed texture, aroma and flavor. Instrumental measurements included near-infrared spectroscopy and compression tests, which correlated well with the sensory data. In another study, 12 cultivars of blueberries were studied by Saftner *et al.* (2008). Consumer testing was performed to find relationships between sensory and instrumental quality.

There were no studies conducted on sensory evaluation on a category of fruit preparations, with the aim to characterize the sensory profile of the products. Also, there was no research performed on sensory, chemical or physical characterizations of strawberry fruit preparations. The aims of the current study are (1) to characterize the sensory properties of a wide range of strawberry jams and (2) to determine if it may be possible to develop a sensory standard for strawberry jams that is applicable in many countries.

MATERIALS AND METHODS

Samples

Twenty-five strawberry jams (Table 1) were studied. All of the samples were assigned three-digit random codes. The samples were purchased up to 1 month before analysis and stored according to the instructions given on the package. All samples were purchased from supermarkets in Tallinn, Estonia and were of Estonian ($n = 5$), Finnish ($n = 2$), Danish ($n = 6$), Norwegian ($n = 1$), Swedish ($n = 1$), Spanish ($n = 2$), German ($n = 3$), Greek ($n = 1$), French ($n = 2$), Lithuanian ($n = 1$) and Hungarian ($n = 1$) origin. Except for sample Est5, that was stored refrigerated (6–10C), the samples were stored at room temperature. Two samples were manufactured with artificial sweeteners and without any added carbohydrates. Three samples were labeled as diet preparations or the word "fructose" was mentioned in the product name (fructose or fructose syrup was used in the product formulation). Two samples claimed to be organic and one sample was prepared with berries and sucrose alone. The samples contained 35–102 g of berries per 100 g product and 0–65 g carbohydrates per 100 g of product.

Sensory Analysis

A trained panel of eight panelists used descriptive sensory analysis to describe the strawberry jams. The sensory laboratory was equipped with individual booths and computers according to ISO 8589-2007. All of the panelists had previous experience in descriptive sensory analysis with various food products and were employees of the Competence Center of Food and Fermentation Technologies in Tallinn, Estonia. The panelists were trained during 15 sessions each lasting 1.5 h, where the attributes, definitions and reference materials were agreed upon (Table 2). During these sessions, the panelists had access to all the samples to be tested. Samples were described by their appearance, flavor and texture attributes.

The experiment was run in triplicate totaling 11 sessions within 4 weeks for sample evaluation. The panelists used a data collection program, written internally, to enter scores. Panelists who missed a session or a product in the testing were coded as missing for that data, but their other data was used. A scale with 0.5 point increments, where 0 = none and 15 = very strong, was used. Unsalted crackers and purified filtered water was available at all times, as well as reference materials and definition sheets. The panelists were told to clean their palates in between the samples and were given breaks between samples. The samples were served in 30 mL plastic cups covered with lids, coded in random three-digit numbers. The serving of the samples was randomized. The samples were prepared 30 min and references were prepared 30 min to 2 h ahead of testing.

Instrumental Measurements

All measurements were carried out in triplicate and the results were averaged. The dry weight of the samples was measured with a MettlerToledo HR83 Moisture Halogen Analyser (MettlerToledo, Columbus, OH) and the Brix using a refractometer, PAL-1 (Atago, Japan), calibrated against distilled water.

Surface color was analyzed using a spectrophotometer CM-600d (Konica Minolta, Japan), calibrated with a white tile; the pH and acidity was measured using a MettlerToledo DL20 Compact Titrator. For pH and titratable acidity measurements, the sample (5 g) was diluted with distilled water (50 g) and homogenized with a homogenizer (Polytron PT 2100, Kinematica, Luzerne, Switzerland) at speed of 11,000 rpm.

TABLE 1. NAMES, COUNTRIES OF ORIGIN AND COMPOSITIONS OF STRAWBERRY JAMS AS GIVEN ON THE LABELING

Sample code	Country of origin	Composition	Amount of berries per 100 g	Amount of carbohydrates per 100 g
Den1	Denmark	Strawberries, thickening agent (pectin, xanthan gum), preserving agent (potassium sorbate) and sweetener (sucralose)	102	4.6
Den2	Denmark	Starch syrup, strawberries, sugar, water, thickening agents (E440, E415), acidity regulator (E330), preserving agent (E202)	35	44
Den3	Denmark	Strawberries, sugar, glucose-fructose syrup, water, gelling agent (fruit pectin), acidity regulator (lactic acid), preserving agent (potassium sorbate)	35	63
Den4	Denmark	Strawberries 40%, sugar, glucose syrup, water, fruit pectin, citric acid, potassium sorbate	40	65
Den5	Denmark	Organic strawberries, organic sugar, water, gelling agents (E440, E415), acidity regulator (E330, E333)	50	45
Den6	Denmark	Strawberries, sugar, glucose-fructose syrup, water, thickening agents (E440, E410), acidity regulator (E330), preserving agent (E202)	40	45
Est1	Estonia	Sugar, strawberries, water, gelling agent (pectin), acidity regulator (citric acid), preserving agent (potassium sorbate)	40	44
Est2	Estonia	Strawberries, sugar, water, thickening agent pectin, acidity regulator citric acid, preserving agent potassium sorbate	50	52
Est3	Estonia	Sugar, strawberries, water, gelling agent (pectin), acidity regulator (citric acid), preserving agent (potassium sorbate), stabilizer (calcium chloride)	35	55
Est4	Estonia	Strawberries, sugar, drinking water, thickening agent pectin, acidity regulator citric acid	43	45
Est5	Estonia	Strawberries 75%, sugar	75	25
Fin1	Finland	Strawberries, sugar, water, gelling agents (E440, E410), acidity regulators (E330, E333), preserving agent (E202), aroma and color agents (E120, E160a)	40	46
Fin2	Finland	Sugar, strawberries, water, gelling agents E440, E415, acidity regulator E330, preserving agent E202	35	47
Fra1	France	Strawberries, sugar, cane sugar, lemon juice concentrate, thickening agent pectin, acidity regulator (E330)	50	50
Fra2	France	Strawberries 60%, cane sugar, water, fruit pectin, concentrated lemon juice, citric acid	60	43
Ger1	Germany	Fructose syrup, strawberries, gelling agents (pectin), acidifying agent (citric acid)	50	45
Ger2	Germany	Fructose syrup, strawberries, gelling agent (pectin), acidity regulators citric acid and calcium citrate, vegetable fats	50	41
Ger3	Germany	Strawberries, sugar (sugar and corn syrup), gelling agent (pectin), acidifying agent (citric acid)	50	63
Gre1	Greece	Fruit, glucose-fructose syrup, solidifying agent (pectin), acidity regulator(citric acid)	45	65
Hun1	Hungary	Fructose-glucose syrup, strawberries (at least 35 g/100 g), sugar, elderberry juice, acidity regulator E330, thickening agent (apple pectin)	35	59
Lit1	Lithuania	Sugar, strawberries, drinking water, solidifying agent pectin, acidity regulator citric acid	35	54
Nor1	Norway	Sugar, strawberries, water, thickening agent (pectin), acidity regulator (citric acid), preserving agent (potassium sorbate)	40	51
Spa1	Spain	Strawberries, fructose, pectin E440, citric acid E330, potassium sorbate E202	55	42
Spa2	Spain	Strawberries, water, thickening agent: fruit pectin, citric acid, preservative (E202), sweetener (E955), food color (E120)	60	0
Swe1	Sweden	Strawberries, sugar, glucose-fructose syrup (wheat), water, thickening agent (E440 – pectin), acidity regulator (E330 – citric acid), preserving agents (E211 – sodium benzoate, E202 – potassium sorbate)	45	43

E120, carmines, coloring agent; E160a, β-carotenes, coloring agent, E202, potassium sorbate, preserving agent; E211, sodium benzoate, preserving agent; E330, citric acid, acidity regulator; E333, calcium citrate, acidity regulator; E410, locust bean gum, stabilizer, thickener; E415, xanthan gum, stabilizer, thickener; E440, pectins, stabilizer, thickener; E955, sucralose, sweetener.

TABLE 2. ATTRIBUTES, DEFINITIONS AND REFERENCE MATERIALS USED IN SENSORY ANALYSIS OF STRAWBERRY JAMS

Attribute	Definition	Reference, definition and preparation
Red	Red color intensity of the sample	Jam2 = 7.0. Preparation: heat frozen strawberries (Maahärra maasikad, Premia Foods AS, Estonia) with water in a pot for 10 min, add sugar (White sugar, Danisco, Denmark; strawberries : sugar : water 35:55:10), heat for 30 min.
Brown	Brown color intensity of the sample	Jam2 = 7.0.
Whole berries	Amount of whole or almost whole berries in the sample	Jam1 = 8.5. Preparation: heat frozen strawberries (Maahärra maasikad, Premia Foods AS, Estonia) with sugar (White sugar, Danisco, Denmark) and water (strawberries : sugar : water 35:55:10) in the microwave-oven for 5 min.
Berriness	Overall quantity of berries in sample	Jam1 = 8.5.
Thickness	Depends on the amount of stabilizers or thickeners used in the sample, characterizes gel-like structure	Jam1 = 3.0, Jam2 = 8.0.
Granular	Structure resembling broken gel, depends on the nature or amount of thickeners or gelling agents used	Broken marmalade (Trulla, Marmiton, Estonia) = 7.5. Preparation: break the marmalade in a kitchen blender for 5 s.
Heated strawberry	Flavor characteristic to heated strawberry products	Jam2 = 12.0.
Fresh strawberry	Flavor characteristic to fresh strawberries	Jam1 = 12.0.
Artificial strawberry	Non-natural strawberry flavor	Strawberry jelly powder (Galaretka, Poland) = 9.0.
Brown sweet	Caramel-like flavor and aroma composition associated with heated sucrose	Brown sugar (Danisco, Denmark) solution = 10.0. Preparation: dissolve brown sugar in water 1:5.
Sweet	Basic taste characterized by sucrose solution	2% sucrose = 2.0, 4%sucrose = 4.0, 6%sucrose = 6.0, 8%sucrose = 8.0, 10%sucrose = 10.0.
Sour	Basic taste characterized by citric acid solution	0.025%citric acid = 2.5, 0.05%citric acid = 3.5, 0.08%citric acid = 5.0, 0.1%citric acid = 7.0.
Bitter	Basic taste characterized by caffeine solution	0.01%caffeine = 2.0, 0.02%caffeine = 3.5, 0.035%caffeine = 5.0.
Astringent	Mouthfeel caused by potassiumaluminiumsulfate or alum solution	0.05%alum = 2.5, 0.1%alum = 5.0.

Rheological analysis was carried out with a Texture Analyzer, T.A.XT.Plus (Stable Microsystems, Surrey, U.K.) using a 40 mm diameter cylinder probe. The samples were compressed with speed 1.0 mm/s and the load cell with 5 kg. Hardness of the samples was measured as force (g) was required to penetrate 15 mm into the sample.

The concentrations of sugars (maltotriose, disaccharides, glucose and fructose) and organic acids (malic acid and citric acid) in the strawberry jams were analyzed by high-pressure liquid chromatography (Alliance; Waters Corp., Milford, MA) using a Bio-Rad HPX-87H column (Hercules, CA) and isocratic elution at a flow rate of 0.6 mL/min with 0.005 M H_2SO_4 at temperature 35C. A refractive index detector (model 2414; Waters Corp.) and dual λ absorbance detector (model 2487; Waters Corp.) were used for detection and quantification of the sugars and acids. The samples of jams (1 g) and distilled water were homogenized (11,000 rpm, 4 min), centrifuged (3,500 rpm, 10 min) and supernatant was diluted (10×) in elution. Data processing was performed using Empower software (Waters Corp.).

Statistical Analysis

The data was analyzed using XL Stat version 10.0 (AddinSoft, New York, NY). Analysis of variance (ANOVA) was performed and significant differences ($P = 0.05$) between samples were found using Fisher's protected least significant difference. Principal component analysis (PCA), was used to visualize main variations between samples' sensory properties, and Pearson correlation coefficients were calculated between sensory and instrumental measurements. The samples were clustered using K-means clustering.

RESULTS AND DISCUSSION

Sample Comparison

Significant differences between certain samples were found for all of the sensory attributes evaluated (Table 3). The attribute "whole berries" varied from 0.2 to 9.0 in intensity with sample Fin2 being significantly higher than the rest of

TABLE 3A. LEAST SIGNIFICANT DIFFERENCE MEANS FOR SAMPLES

Sample	Whole berries	Berriness	Thickness	Granular	Heated strawberry	Fresh strawberry	Artificial strawberry	Brown sweet	Sweet	Sour	Bitter	Astringent	Color red	Color brown
Den1	1.14	7.41	9	1.09	6.27	0.74	1.14	3.36	5.16	3.05	2.4	1.75	3.64	10.09
	jklm	de	jk	hi	ij	i	cde	bcd	i	abc	a	a	i	a
Den2	6.04	8.7	9.35	0.95	7.57	2.13	0.86	4.07	7.5	2.72	1.72	1.5	5.24	7.67
	b	abcd	ijk	hi	ghij	abcdefgh	e	bc	cdefgh	bcdef	b	abc	fgh	bc
Den3	0.2	3.78	12.2	4.28	8.91	1.8	1.84	3.24	8.61	2.39	1.24	1.24	6.87	4.91
	m	h	a	b	abcdefgh	abcdefghi	c	bcde	ab	cdefg	b	bc	bcd	hij
Den4	1.66	5.8	11.57	1.55	9.86	1.33	1	3.98	8.8	1.98	1.18	1.25	6.76	5.55
	hijk	fg	abc	hi	abcdef	fghi	de	bc	a	g	b	abc	bcd	ghij
Den5	1.84	7.46	10.27	3.29	7.91	1.48	1.34	3.36	6.57	3.52	1.77	1.57	5.6	7.41
	ghij	cde	fgh	bcd	efghij	defghi	cde	bcd	h	a	ab	abc	ef	bcd
Den6	2.85	7.96	9.04	1.09	9.28	2.78	1.2	3.78	7.48	2.41	1.24	1.3	6.93	5.71
	efg	bcd	jk	hi	abcdefg	ab	cde	bc	defgh	cdefg	b	abc	bcd	fghij
Est1	4.85	7.87	9.23	2.04	10.33	2.67	1.54	3.98	8.88	1.98	1.29	1.35	6.42	6.07
	c	bcd	ijk	defgh	ab	abc	cde	bc	a	g	b	abc	cde	defgh
Est2	4.39	8.98	10.43	1.76	8.76	1.74	1.5	3.78	7.78	2.41	1.8	1.48	7.05	6.45
	cd	ab	efg	fghi	abcdefgh	abcdefghi	cde	bc	bcdef	cdefg	ab	abc	bc	cdefg
Est3	1.52	5.27	8.86	1.91	8.61	1.62	1.43	2.55	7.75	2.41	1.36	1.18	6.41	5.36
	ijk	fg	k	efgh	abcdefgh	bcdefghi	cde	def	bcdef	cdefg	b	bc	cde	ghij
Est4	3.11	8.39	8.91	1	8.68	1.24	0.9	4.25	7.95	2.23	1.5	1.25	4.38	7.91
	ef	bcd	k	hi	abcdefgh	hi	de	abc	abcdef	defg	b	abc	ghi	b
Est5	4.57	8.11	4.15	0.59	8.28	1.28	1.36	5.24	7.7	2.54	1.8	1.52	3.54	10.52
	cd	bcd	m	i	cdefghi	ghi	cde	a	bcdefg	cdefg	ab	abc	i	a

Within a column, samples marked with different letters are significantly different at 95% confidence level.

the samples. The next sample that was unique from the rest of the samples for the whole berry attribute was Den2 (mean 6.0). The remaining samples varied from 0.2 to 4.8 in the whole berries attribute. All values were in the slight range of the intensity scale, meaning, the berries used in the majority of samples were extensively homogenized. The berries in sample Fin2 may have been pretreated as suggested by Suutarinen *et al.* (2000, 2002). This sample also was exceptionally hard by texture when compared to other samples. The hardness of the samples varied from 81 to 227 g, with the exception of sample Fin2 that was measured at 805 g (Table 4).

Sensory analysis scores and the actual product's berry content are not necessarily related and should be differentiated. The berriness attribute, showing the overall perceived berry amount in the jam, varied from 3.3 to 9.9 in intensity. There were no significant differences in berriness (7.8–8.4) between samples Fra1, Est4, Ger3, Est5, Den6 and Est3, although according to the ingredients, 35–67 g of berries were used per 100 g of jam. Also, samples Est1, Fin1, Swe1, Den4 and Ger2 did not have significant differences in berriness (5.3–6.0). These samples were manufactured from 40 to 50 g of berries per 100 g of product. Formulation, processing and stabilization appear to play an important part in how the jam is perceived.

Thickness of the samples varied from 4.1 to 12.2. Two samples were significantly different from the other samples and also from each other. Sample Swe1 had a thickness mean value of 7.9, and sample Est5 had a mean value of 4.1, making it the lowest among the samples. Sample Est5 was the only sample manufactured with 75% strawberries and 25% sucrose alone – no thickening or stabilizing agents were used according to the labeling. Although sucrose can be used as a thickening agent, pectin is normally used to make the jams viscous (Grigelmo-Miguel and Martin-Belloso 1999; Maceireas *et al.* 2007).

Samples Fin1 and Fra2 had the highest granular texture and were significantly different from the rest of the samples. Sample Fin1 was manufactured from strawberries, sugar, water, gelling agents (pectin and locust bean gum), acidity regulators (citric acid and calcium citrate), preserving agent (potassium sorbate), aroma and coloring agents (carmines, β-carotenes). Sample Fra2 was manufactured from strawberries (60%), cane sugar, water, fruit pectin, concentrated lemon juice and citric acid. Locust bean gum was used in samples Fin1 and Den6. However, sample Fra2 did not contain any thickening agents other than pectin. Sugar crystallization could cause the granular structure to occur if the jam sugar content was high enough to cause a saturated solution. It appears that the granular texture is more likely the result of processing conditions or amounts of thickening agents used in the formulation.

The artificial strawberry attribute varied from 0.8 to 4.6 in intensity. Samples evaluated as the most artificial were Gre1, Fin1 and Hun1. Although sample Hun1 was significantly

TABLE 3B. LEAST SIGNIFICANT DIFFERENCE MEANS FOR SAMPLES

Sample	Whole berries	Berriness	Thickness	Granular	Heated strawberry	Fresh strawberry	Artificial strawberry	Brown sweet	Sweet	Sour	Bitter	Astringent	Color red	Color brown
Fin1	0.35	5.28	11.89	6.55	7.8	1.45	2.61	3.46	7.13	2.2	1.37	1.33	5.91	7.2
	lm	fg	ab	a	fghij	efghi	b	bcd	efgh	efg	b	abc	def	bcde
Fin2	9.02	9.93	10.61	0.95	10.52	2.54	0.98	3.52	7.8	2.25	1.28	1.2	7.26	5.98
	a	a	defg	hi	a	abcde	de	bcd	bcdef	defg	b	bc	abc	efghi
Fra1	3.04	8.44	11.2	2.93	10.22	2.43	1.41	4.3	8.33	2.26	1.5	1.35	6.85	6.34
	ef	bcd	bcde	cdefg	abc	abcdefg	cde	ab	abcd	defg	b	abc	bcd	cdefg
Fra2	3.78	8.98	10	5.65	8.35	2.04	1.07	4.24	6.78	2.36	1.59	1.35	5.43	7.95
	cde	ab	ghi	a	bcdefgh	abcdefgh	de	abc	gh	cdefg	b	abc	efg	b
Ger1	2.45	7.46	11.66	3.11	8.05	1.69	1.41	3.23	6.75	2.91	1.59	1.4	5	7.31
	fghi	cde	abc	bcde	defghi	bcdefghi	cde	bcde	gh	abcd	b	abc	fgh	bcde
Ger2	1.2	5.98	9.5	2.14	8	1.31	1.36	4.16	7.41	2.8	1.68	1.52	4.23	8.2
	jklm	fg	hijk	defgh	defghi	fghi	cde	abc	defgh	bcdef	b	abc	hi	b
Ger3	3.65	8.24	11.36	3	10.02	2.65	1.18	3.2	8.43	2.67	1.39	1.48	8.13	4.85
	de	bcd	abcd	bcdef	abcd	abcd	cde	cde	abc	bcdef	b	abc	a	hij
Gre1	0.52	4.73	10.89	3.84	7.18	1.31	3.02	2.17	8.05	2.14	1.25	1.36	7.52	4.66
	klm	gh	cdef	bc	hij	fghi	b	ef	abcde	fg	b	abc	ab	ij
Hun1	0.33	3.36	8.74	3.98	5.83	0.69	4.62	1.93	7.08	3.26	1.25	1.69	7.14	4.52
	lm	h	k	bc	j	i	a	f	fgh	ab	b	ab	abc	j
Lit1	3.68	7.48	9.36	1.61	9.61	1.64	0.91	3.88	8.5	2.36	1.24	1.39	6.34	7.03
	de	cd	ijk	ghi	abcdefg	bcdefghi	de	bc	ab	cdefg	b	abc	cde	bcdef
Nor1	3.87	7.39	9.2	1.28	9.91	2.89	1.5	3.39	8	2.57	1.27	1.46	6.82	5.63
	cde	de	ijk	hi	abcde	a	cde	bcd	abcdef	cdefg	b	abc	bcd	fghij
Spa1	1.5	6.11	10.93	3.91	7.77	1.5	1.63	4.22	6.61	2.24	1.59	1.39	3.54	7.91
	ijkl	ef	cdef	bc	fghij	cdefghi	cd	abc	h	defg	b	abc	i	b

Within a column, samples marked with different letters are significantly different at 95% confidence level.

higher in artificial flavor from Gre1, Fin1 and the other samples, all of the intensities of the artificial strawberry attribute were scored in the slight range on the scale.

The heated strawberry attribute (the flavor typical of thermal treatment to strawberry products) varied from 5.8 to 10.5 in intensity. Two samples (Hun1 and Spa2) were significantly lower (5.8) in the heated strawberry attribute. Five samples (Est3, Ger3, Fin2, Den6 and Nor1) with the highest intensities of heated strawberry surprisingly were also five of the highest in fresh strawberry flavor. Overall, strawberry flavor in these samples was the highest among all of the jams. The samples came from five different countries of origin: Estonia, Finland, Denmark, Norway and Germany, again suggesting that a particular quality attribute is not specific to a country, nor do all the products from that origin have the same characteristics. The strawberry content of those jams varied from 35 to 50% and the carbohydrates content from 45 to 63%. There were two samples (Den1 and Hun1) that had the lowest intensities in the fresh strawberry flavor and were significantly different from other samples; they also had low intensities (6.3 and 5.8, respectively) in the heated strawberry attribute. As reported by King *et al.* (2006), sucrose or carbohydrates may accent the strawberry flavor. Sample Den1 was manufactured with 102 g of strawberries per 100 g of jam, but no sugar or syrup was used. Sample Hun1 was manufactured with at least 35 g of strawberries per 100 g of jam, which is the legal minimum amount if the product is labeled as "jam." The quality and the amount of raw material used in the manufacturing is an important consideration in the final product's overall quality.

The mean intensity of sweetness in the samples varied from 4.8 to 8.8. Alves *et al.* (2008) found consumers prefer sweeter

TABLE 3C. LEAST SIGNIFICANT DIFFERENCE MEANS FOR SAMPLES

Sample	Whole berries	Berriness	Thickness	Granular	Heated strawberry	Fresh strawberry	Artificial strawberry	Brown sweet	Sweet	Sour	Bitter	Astringent	Color red	Color brown
Spa2	2.74	8.76	9.8	1.93	5.85	2.41	1.54	1.65	4.87	1.98	1.41	1.09	5.48	5.68
	efgh	abc	ghij	efgh	j	abcdefgh	cde	f	i	g	b	c	ef	fghij
Swe1	0.9	5.31	7.9	1.73	8.23	2.46	1.61	4.09	7.09	2.83	1.63	1.4	5.21	7.31
	jklm	fg	l	fghi	cdefghi	abcdef	cde	bc	fgh	bcde	b	abc	fgh	bcde

Within a column, samples marked with different letters are significantly different at 95% confidence level.

TABLE 4. BRIX, PH, COLOR, DRY WEIGHT, AND HARDNESS DATA

Sample	Dry weight (%)	Brix (%)	pH	L	a	b	Hardness (g)
Den1	11.19	8.8	3.92	38.4	0.3	2.1	96
Den2	51.97	44	3.55	37.5	0.3	2.0	107
Den3	80.79	67.1	3.41	38.0	0.4	2.0	163
Den4	72.59	62.7	3.52	37.9	0.2	2.1	154
Den5	46.08	46.2	3.47	38.3	0.4	2.1	100
Den6	47.24	46.2	3.59	38.1	0.3	2.0	92
Est1	52.41	41.8	3.65	38.5	0.5	2.1	81
Est2	57.87	50.6	3.63	38.5	0.4	2.1	127
Est3	68.81	59.4	3.53	38.8	0.3	2.1	101
Est4	53.20	45.1	3.61	38.7	0.3	2.2	113
Est5	50.76	44	3.64	38.3	0.2	2.0	75
Fin1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fin2	56.93	46.2	3.55	38.0	0.3	2.0	806
Fra1	70.47	61.6	3.45	37.9	0.3	2.1	108
Fra2	N/A	40.7	3.86	38.2	0.2	2.0	N/A
Ger1	51.05	41.8	3.44	38.2	0.3	2.1	228
Ger2	47.87	40.7	3.53	37.6	0.2	2.1	103
Ger3	70.57	59.4	3.35	37.7	0.3	2.1	113
Gre1	71.80	62.7	3.37	38.5	0.4	2.1	166
Hun1	70.67	56.1	3.23	38.2	0.2	2.0	89
Lit1	80.01	52.8	3.60	37.7	0.2	2.1	95
Nor1	55.36	48.4	3.63	37.7	0.3	2.1	82
Spa1	47.87	45.1	3.59	38.0	0.3	2.1	158
Spa2	7.11	5.5	3.82	38.2	0.4	2.1	216
Swe1	46.11	40.7	3.77	38.1	0.2	2.0	83

L, luminosity; a, redness; b, yellowness.

jams and least accept low-calorie products and products with low sweet intensities. Samples Spa2 and Den1 were evaluated as having the least sweet taste within the sample set, and both of these samples were manufactured with sucralose and no other sweeteners. Consumers also prefer strawberry jams that are lighter in color and red (Alves *et al.* 2008). The red color intensity varied from 3.5 to 8.1, and the brown color intensity from 4.5 to 10.5. Samples that had high intensities of red color (Gre1, Ger3, Hun1), had lower intensities of brown color and vice versa for samples Den1, Ger2, Est4, Spa1 and Est5. These results suggest that samples Gre1, Ger3 and Hun1 would be preferred among the consumers, but this study did not measure consumer acceptance. According to Wicklund *et al.* (2005), jams stored at 4C had better color quality than jams stored at room temperature. Although sample Est5 was stored at a lower temperature than the other samples, the color of the sample was brown. This may be the result of ingredient and processing decisions.

Relationship of Measurements

The correlations between sensory and instrumental measurements showed that the sweet attribute was correlated with total sugars (0.88), glucose (0.68), sucrose (0.71), Brix (0.89) and the dry weight of the samples (0.91). The sweetness of the samples was mainly the result of sugars added to the formulation, as strawberries contain an average of 7.3 g of sugars/100 g (Danish Food Composition Databank). The sweet attribute also was correlated with the heated strawberry attribute (0.76) as illustrated in Fig. 1.

The sour attribute was correlated with astringent mouthfeel (0.80) and with titratable acidity (0.69), but not with total acid content of the samples. The reason for this could be the sweet taste masking the sour in the sensory perception.

Bitterness was negatively correlated with red color (–0.67) and dry weight of the samples (–0.62), but had a high positive correlation with the brown color attribute (0.80) and astringent mouthfeel (0.60). Processing conditions, probably involving high temperature and/or time, probably resulted in

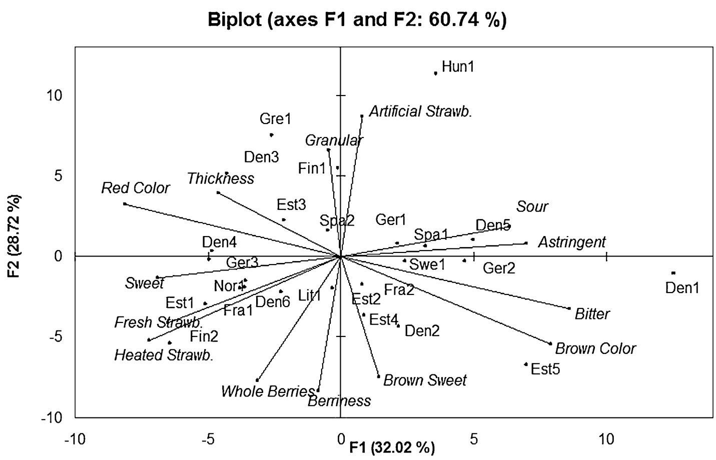

FIG. 1. PCA BIPLOT OF STRAWBERRY JAMS' SENSORY ANALYSIS DATA

TABLE 5. K-MEANS CLUSTERING RESULTS OF STRAWBERRY JAMS' SENSORY ANALYSIS RESULTS

Class	1	2	3
Objects	9	6	10
Samples	Den4, Den6, Est1, Est2, Fin2, Fra1, Ger3, Lit1, Nor1	Den3, Est3, Fin1, Gre1, Hun1, Swe1	Den1, Den2, Den5, Est4, Est5, Fra2, Ger1, Ger2, Spa1, Spa2
Description	Red-colored, sweet, high berriness, high strawberry flavor intensity	Artificial flavor, thick granular texture	Brown-colored, bitter, sour, astringent not high strawberry flavor intensity

Maillard reactions in the jams, which makes it possible for the brown color to develop.

The appearance attribute "whole berries" and the flavor attribute "berriness" were strongly correlated (0.81). Whole berries also correlated with the hardness of the samples (0.61). The more berries in the sample recipe, the stronger the resulting product. The berriness attribute was in negative correlation with the artificial strawberry attribute (–0.69) and also the granular attribute (–0.64). Samples having high amounts of berries do not need to be strengthened further with stabilizers. However, samples containing lower amounts of berries in the formulation need to be stabilized and the low strawberry flavor may result in an impression of being artificial. Artificial strawberry flavor was also negatively correlated with the brown sweet attribute (–0.60), and was positively correlated with maltotriose content of the samples (0.63, data not shown). This suggests higher maltotriose concentrations in strawberry jams may result in a perception of the flavor being artificial. Samples Den4, Gre1, Hun1 and Ger3 had a maltotriose content higher than 2%. Samples Gre1 and Hun1 were stronger in the artificial aromatics than the other samples. Whether this relationship can be associated with maltotriose content, needs further study.

There were some significant correlations present between the different instrumental measurements. For example, the pH measurements were negatively correlated to the dry weight measurements (–0.76), Brix (–0.70) and to total sugars (–0.62). The citric acid content was positively correlated with total acid content (0.58), which underlines the importance of citric acid in strawberry jam formulations.

Principal Component Analysis and Cluster Analysis

The first principal component (PC) explained 32% and the second explained 28% of the variation among the samples (Fig. 1). The third and fourth PC did not explain the variability among the samples any further and thus were not presented. PC 1 explained differences in the heated strawberry flavor and red-color samples and the brown-colored samples with sour and bitter flavor and astringent mouthfeel. PC 2 explained differences in artificially flavored samples and the samples with a high amount of berries.

The clustering results (Table 5) can be combined with the PCA results. The first cluster was composed of red-colored sweet samples, with most of them having high amounts of berries. Strawberry jams in Cluster 1, according to Table 1, were composed of 35–50 g/100 g of strawberries and a sweetening agent (i.e., sucrose and corn or glucose syrup), making the carbohydrate content 44–65 g/100 g. Additives, such as a thickening agent (usually pectin), acidity regulator (e.g., citric acid) and a preserving agent (e.g., potassium sorbate or similar), were also added. Water was used in seven of the jams in Cluster 1.

The second cluster was comprised mostly of samples having artificial flavors and a thick granular texture, which probably was caused by the choice or the amount of stabilizer used in the recipe. This cluster was the smallest, composed of only of six samples. There were two ingredients (strawberries and pectin) that were used in all of the samples in this cluster. However, there were several ingredients that might cause differentiation of this cluster and that were not used frequently in other samples tested: elderberry juice was used in sample Hun1, carmines and β-carotenes were used in sample Fin1, calcium chloride as a stabilizer in sample Est3, sodium benzoate was used in sample Swe1 and lactic acid in sample Den3. The berry and carbohydrate content varied 35–45 g/100 g and 43–65/100 g, respectively.

The third cluster was comprised of samples that were brown in color, bitter, sour, had an astringent mouthfeel and did not contain high strawberry flavor intensity. Jams in Cluster 3 were mainly specialty products: organic, artificially sweetened, manufactured from 100% of berries or diet preparations. This indicates a problem area in specialty jam development and suggests that such jams may not meet expected standards of quality without further development. Clearly, there is a challenge for product development in that section of the category.

Development of a Standard

Based on this data, a standard based on origin probably would be inappropriate for strawberry jams. However, specifying sensory attributes that may be evaluated when determining sensory quality of a strawberry jam could be of value to food developers. For specialty jams, such as organic or sugar-free products, certain sensory attribute intensities tend to be different than for the regular products manufactured with fruit, sugar, thickener and acidity regulator. The appearance (color and berriness), texture (thickness) and flavor (sourness, bitterness, sweetness, strawberry flavors) are some examples that may be included in a sensory standard defining properties of strawberry jams. Some of these attributes, though, are highly correlated with instrumental measurements, and thus, could be determined either way – using sensory methods or chemical-physical means. Instrumental measurements (such as dry weight or Brix, pH) may be used for some aspects related to prediction of strawberry jam quality, sweetness and sourness of the sample. Some attributes, like fresh and heated strawberry flavor intensities, astringency, bitterness or flavor notes not necessarily part of a high-quality product (fermented, moldy, vinegar, etc.) would need to be evaluated using sensory testing.

CONCLUSIONS

Strawberry is one of the most popular flavors used in food products. Samples in this study formed three clusters: (1) jams that were sweet, red in color and high in berry content; (2) jams with a granular structure and artificial flavor; and (3) brown-colored, sour and astringent jams that tended to be low in berry content. It was obvious that the country of origin did not affect composition or quality of the product and, thus, a PDO would not be appropriate in terms of sensory quality for strawberry jams. The study indicates that aspects of the strawberry jam category such as specialty products, such as organic or sugar-free products may need further development and should be studied further.

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Article IV

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Flavour and Acceptance of Estonian Cheeses

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Abstract. The flavour and acceptance of locally manufactured cheeses in Estonia were studied. The 36 cheeses, varying in texture, manufacturing technology, fat content, and additives, were described by 32 flavour attributes. Estonian cheese was described as milky and buttery, with sweet aromatics, occasionally with biting and butyric acid aromatics. The cheeses are usually not highly aged, and thus do not have dominant astringent or bitter sensations found in cheeses from other countries.

Based on a cluster analysis of the flavour of the cheeses, four were chosen for an acceptance study. One hundred and eleven consumers in Estonia tested the four cheeses. Cluster analysis of the consumers' liking scores indicated two clusters of consumers, one cluster preferring the younger cheeses and the second cluster preferring more aged cheeses. The study provides information concerning cheese flavour and preferences in an area of Eastern Europe which has been lacking in previous literature.

Keywords: cheese, flavour, liking, sensory

INTRODUCTION

The sensory properties of specialty cheeses from around the world, including those from specific regions or specific types have been characterized by several authors (Chambers et al., 2010; Drake et al., 2001; Ritvanen et al., 2005). Numerous studies have been conducted to develop lexicons for describing cheese flavour (Rètiveau et al., 2005; Drake et al., 2001; Heisserer & Chambers, 1993). Attributes have been categorized into seven categories including, fundamental tastes, dairy aromatics, fatty acid/animal, musty/fungal, aged/fermented, and other aromatics and mouthfeel.

However, literature is lacking on information on Eastern European cheese flavour and liking. The objective of this study was to 1) describe the flavour of Estonian cheeses and 2) determine acceptability for those cheeses among Estonian cheese consumers.

MATERIALS AND METHODS

Samples

Sample cheeses (n = 36) from eight different manufacturers were used in descriptive sensory analysis. The samples were assigned random three-digit numbers. These samples included a mould-ripened cheese (198), smoked cheeses (776, 431), reduced fat-cheeses (211, 411, 628, 836), a cheese with caraway seeds (327), with probiotic bacteria (297, 295), Gouda (408, 107), Edam (580, 819, 173), Havarti (434) and Swiss (516). The types or properties of the rest of the samples were not specified by the manufacturer. All cheeses were manufactured in Estonia from cow's milk. All samples used in descriptive analysis were available in 2009 and 2010 in grocery stores in Tallinn, Estonia. For descriptive sensory analysis the samples were shipped to the Sensory Analysis Center, Manhattan, KS, US within a week from purchasing. The samples were stored at the recommended temperature and analyzed within a month of receipt; always before the "best before"-date.

Descriptive Sensory Analysis

Six highly trained panellists from the Sensory Analysis Center at Kansas State University evaluated the samples in three repetitions in completely randomized order during 19 1.5 h sessions. The panellists had more than 120 h of training, average more than 1000 h of testing experience, and had prior experience testing cheese. For testing, the samples were cut into 1.2 cm cubes, placed into disposable 90 ml plastic cups and covered with lids, labelled with a three-digit code and held at room temperature for approximately one hour before analysis. Most attributes used had been defined and referenced in previous studies (see e.g., Retiveau, et al., 2005) and included dairy notes (buttery, cooked milk, dairy fat, dairy sour, dairy sweet), fundamental tastes (sweet, salty, sour, bitter, umami), fungal (musty, mouldy), animal (decaying animal, butyric, goaty, sweaty), aged/fermented (aged, fermented, fruity, sauerkraut), mouthfeel attributes (astringent, chalky, biting, pungent, sharp), and other aromatics (caraway, floral, green, nutty, smoky, sweet aromatics, waxy). Caraway, defined as 'the aromatics associated with caraway seeds, such as dry, slightly pungent, woody, and 'has a slight, somewhat floral aroma'; 'it may also have a slight anise aromatic', was added to the lexicon because one sample was enriched with caraway seeds. Unsalted crackers and purified water was available to panellists for palate cleansing. A 15-point intensity scale, with 0.5 point increments, where 0 would represent none and 15 very strong, was used. Compusense Five version 4.6 (Compusense, Guelph, Ontario, Canada) was used for the sensory analysis data collection.

Consumer Study

For the consumer study four samples (150, 201, 408, and 516) were chosen based on Principal Component Analysis (PCA) results. Sample 381 was used as a warm-up sample to reduce the first sample bias often noted in consumer studies, and results for this sample were not used in data analysis. The samples were purchased from grocery stores in Tallinn in August 2010, and the study was carried out in September 2010 in Tallinn, Estonia. The cheeses were cut into 1.2 cm cubes and placed into covered 40 ml disposable plastic cups, labelled with three-digit codes. The samples were served at room temperature.

One hundred-and-eleven adult consumers (33 men and 78 women), who identified themselves as cheese consumers, were recruited via e-mail and fliers in Tallinn, Estonia. The consumers tasted the cheeses in a single session. A break of 2-3 min was provided between samples, and consumers were encouraged to take a bite of unsalted cracker and drink the purified water that was provided during these breaks. The cheeses were presented individually in a randomized order. The ballot for each cheese included questions on cheese liking (overall liking, flavour liking, dairy flavour liking, sweet, sour, and bitter taste liking) on a 9-point hedonic scale, where 1 = dislike extremely and 9 = like extremely.

Statistical Analysis

XL Stat version 10.0 (AddinSoft 2010, New York, NY, USA) was used for clustering the descriptive sensory analysis data, correlation analysis (using Pearson correlation coefficients, $P = 0.05$), and for PCA. Caraway and smoky attributes, and sample 198 were removed from the data before PCA analysis was performed. Significant differences ($P = 0.05$) between samples and consumer clusters were detected with Analysis of Variance (ANOVA). The samples and consumers were clustered using Agglomerative Hierarchical Clustering (AHC). All samples and attributes were included in the clustering, as were all the consumers.

RESULTS AND DISCUSSION

The Flavour of Estonian Cheese

The mean scores of the descriptive sensory analysis suggested that the majority of Estonian cheeses have a mild, dairy-like character. The cooked milk, buttery, dairy fat, dairy sour, and dairy sweet attributes were scored low (0.5 – 5.0) for all samples. The fundamental tastes – salty, sour, bitter, umami, and sweet were all present in the flavour composition. The cheeses were evaluated as having sweet aromatics but also as being biting and sharp and causing an astringent mouthfeel. Other aromatics such as nutty, musty, and butyric acid were found for all samples, but the scores for most samples were low. The aged attribute (defined as a clear, distinct aromatic edge sometimes described as sour, astringent, and pungent), frequently seen in aged cheese, was scored in the low range for most cheeses, and in the moderate range (scores 5.5 – 10) for nine of the cheeses.

The nature and flavour of real Estonian cheese and disputes on which manufacturers should be able to use the label 'Eesti Juust' (not a European Protected Designation of Origin label) has occurred on several occasions. Five samples in this study (201, 348, 381, 606, and 769) were labelled as 'Eesti Juust' (i.e., 'The Estonian Cheese' or 'Cheese of Estonia'). Those five samples were manufactured by three different companies; two of the cheeses made by a single manufacturer were in different clusters suggesting that what is considered 'Eesti Juust' is not consistent in flavour within a manufacturer. Based on mean scores, the samples were different in sweet aromatics and the butyric acid aromatics. Sample 606 was found significantly higher in the butyric acid attribute and was different in dairy notes from the rest of the samples. Samples 348 and 381 did not differ in the sweet aromatics but had a difference in aged aromatics. However, a clear profile differentiating these cheeses from the remaining samples was not found.

Four samples (211, 411, 628, 836) were labelled as light products with a fat content of 15 - 19%. None of the reduced fat cheeses were scored similarly to other mild, dairy like cheeses, and all had some strong character notes.

Two samples (295, 297) were claimed as having functional properties based on enrichment with probiotic bacteria, either *Lactobacillus plantarum* TENSIA^{TM} or *Lactobacillus fermentum* ME-3. The flavour properties of these two cheese samples were different from each other. Sample 295 had higher levels of sweet aromatics, and sample 297 was more biting, higher in butyric acid aromatics, and had a stronger fermented flavour.

Principal Component Analysis

Principal Components (PC) 1 and 2 explained 49.26% of the variation within samples (Fig. 1). PC 1 differentiated samples with a chalky mouthfeel and sweet aromatics versus the pungent samples with butyric acid aromatics. The sweet aromatics were correlated with the chalky attribute (0.83, $p = 0.05$) and negatively correlated with the pungent aromatics (-0.71). Samples 772, 819, 344, 150, 381, 295, 516, 327, 107, 912, and 349 were scored highest and not significantly ($p > 0.05$) different from each other for sweet aromatics. The sweet aromatics attribute also was correlated somewhat with the floral (0.63) and the fruity (0.40) attributes. Thus sweet aromatics could partly be caused by esters present in the samples (Gomez-Ruiz et al., 2002).

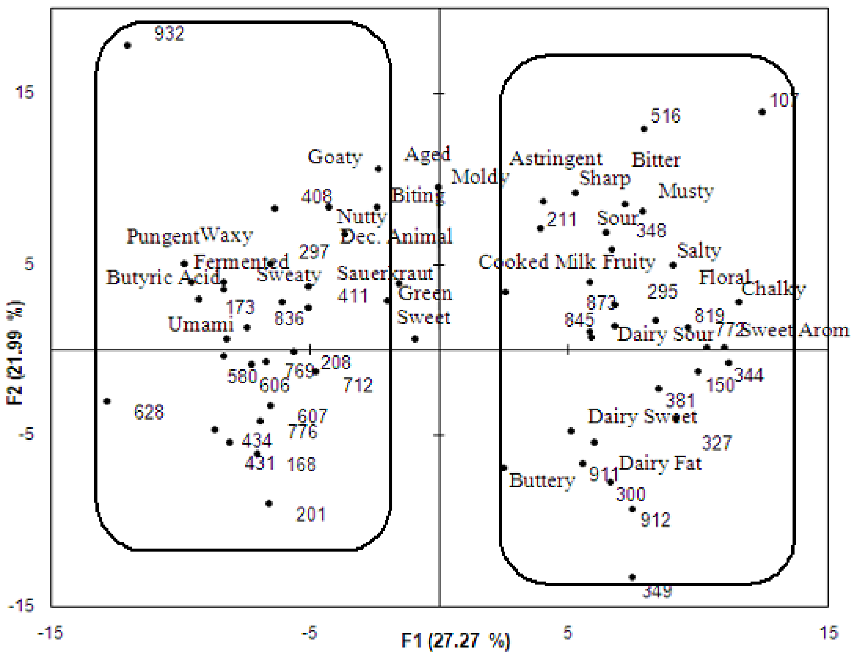

Figure 1. PCA biplot for PC 1 and 2. Sweet Arom – sweet aromatics; Dec. animal – decaying animal. Cluster 4 (except samples 776 and 431) is surrounded with a line as negative loadings of PC1 and cluster 1 as positive loadings of PC1.

Samples 198, 932, 297, 606, and 607 were highest in butyric acid aromatics. Those same samples and sample 776 were highest for pungency, indicating that short chain fatty acids probably were more prevalent in these samples (Gomez-Ruiz et al., 2002). Thus the pungent sensation could be caused by the butyric acid or other organic acids content in these samples, as these two attributes were highly correlated ($R = 0.85$).

PC 2 explained the aged, mouldy, sharp, biting, and astringent mouthfeel attributes. These attributes were in moderate correlation. Samples 932, 408, 107, and 516 scored in the moderate range, but still significantly higher in the aged flavour than the remaining samples. Two of these samples were labelled as Gouda cheese (408, 107) and one sample (516) as Swiss cheese.

Cluster Analysis

Four clusters resulted from cluster analysis. Clusters 1 and 4 were composed of 16 and 17 samples, respectively (Fig. 1). Clusters 2 and 3 were composed of one and two samples, respectively. Based on the PCA results, the samples in Cluster 1 can be characterized as mild, chalky, and having sweet aromatics. The samples in Cluster 4 can be characterized as having pungent and butyric acid aromatics, and some also were fermented, mouldy, sweaty, and biting. The centroid samples for Cluster 1 (819) and for Cluster 4 (580) were labelled as Edam-type cheeses, together with sample 173. However, the descriptive sensory analysis results showed that these cheeses were rather different in flavour. The actual flavour of Edam cheese by standard is poorly described (FAO/WHO, Codex Alimentarius). All of these samples were manufactured in different facilities and different time points. Studies comparing the flavour of Edam-type cheeses manufactured in different countries may explain whether those in Estonia carry different or similar characteristics.

Cluster 2 was composed of one sample, 198, and was the only sample surface-ripened with mould. This sample was higher in the musty, mouldy, green, butyric acid, and decaying animal flavours.

Cluster 3 was composed of two samples, 776 and 431. These samples were both smoke-cured cheeses and were significantly higher in smokiness than the rest of the samples. The samples also were significantly different from each other in smokiness, with sample 776 scoring higher (6.4) than sample 431 (4.5).

Consumer Study

ANOVA within each cluster (Table 1) explained different consumer liking question scores. Cluster 1 liked samples higher in the aged, pungent, and astringent attributes (408 and 516). In Cluster 1 sample 408 was the most liked cheese. In sweet flavour liking both samples 408 and 516 were liked significantly more than samples 201 and 150. In Cluster 2 samples 150 and 201, that were low in the aged, pungent, and astringent attributes, were liked best. Both of these samples were liked significantly more than sample 516 and 408 in all questions except for bitter flavour liking. According to Drake et al. (2001) these cheeses may be described as undeveloped in flavour or young.

Consumer segmentation may occur according to cheese appearance, texture, and flavour (Young et al., 2004). Because appearance and texture, as well as imported cheeses were not the objective of this study further research may be necessary to fully understand cheese liking among Estonian consumers

CONCLUSIONS

Thirty-six cheese samples were analyzed using descriptive sensory analysis. All of the cheeses had low to moderate dairy flavour attributes. The cheeses varied in pungency and butyric properties, sweet aromatics, and more or less characteristics associated with aging. None of the cheeses (with the exception of one mould-ripened cheese) were particularly strong for any characteristics suggesting that these cheeses typically are milder than cheeses found in other countries. Further comparison with cheeses manufactured in other countries may show Estonian cheese flavour in perspective, and it may be possible to specify Estonian cheese characteristics.

Two large clusters of consumers were identified, one of which liked younger cheeses and one that liked more aged cheeses, among those cheeses studied. A study comparing the liking of cheese manufactured in Estonia versus imported cheese may clarify whether consumers in Estonia actually prefer specific flavour characteristics of Estonian cheeses or may in some cases like stronger flavours of imported cheeses.

Table 1. Average scores and differences between consumer cluster 1 and cluster 2.

	Sample	Overall liking		Fl liking		Dairy fl liking		Sour fl liking		Sweet fl liking		Bitter fl liking	
C1	150	6.1	b	5.8	bc	5.6	b	5.2	c	5.6	b	5.3	bc
	201	6.0	b	5.4	c	5.4	b	5.0	c	5.4	b	4.9	c
	408	7.5	a	7.6	a	6.4	a	6.7	a	6.5	a	6.5	a
	516	6.3	b	6.2	b	5.8	b	5.8	b	6.1	a	5.8	b
C2	150	6.7	a	6.5	a	5.9	a	5.8	a	5.9	a	5.4	a
	201	6.6	a	6.2	a	5.9	a	5.6	a	6.1	a	5.6	a
	408	5.0	b	4.4	b	4.9	b	5.0	b	5.0	b	4.6	b
	516	5.3	b	4.7	b	4.9	b	5.1	b	5.1	b	5.0	ab

The means in the same column within cluster with different letters are significantly different ($P = 0.05$). C1, C2 – cluster 1 and 2, respectively. Fl –flavour.

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Article V

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Flavor Comparison of Natural Cheeses Manufactured in Different Countries

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Abstract
The objective of this study was to determine the main flavor components of different natural aged cheese types from various countries and determine whether a specific sensory characteristic exists within specific countries for European cheeses. The flavor of 152 cheeses from Estonia, France, Italy, Germany, Holland, Austria, England, Greece, Ireland, Spain, Switzerland, Sweden, Belgium, and Denmark were described during four independent studies. The sensory data from these studies were combined. The cheeses were sorted according to milk type and texture, and flavor characteristics of these groups were described.
The main flavor characteristics of the cheeses tested were salty, sweet, sour, astringent, biting, pungent, sharp, nutty, musty/earthy, dairy fat, buttery, and dairy sweet. The cluster analysis divided the cheeses into four clusters: clusters 1 and 2 were sour, dairy sour, salty, astringent, biting, and varied in buttery (cluster 1) and sharp notes (cluster 2). Cluster 1 and 2 were mainly composed of French cheeses, while clusters 3 and 4 represented cheeses from various countries. Cluster 3 and 4 were sweet, with cooked milk and nutty characteristics and varied from buttery (cluster 3) to sharp notes (cluster 4). Cheeses from some countries, e.g. France and Estonia, generally exhibited common sensory characteristics within the specific country, but cheeses from some other countries, such as Italy, varied widely, and seemed to have no common sensory theme. Although most regional cheese standards are not specific about flavor profiles, these results suggest it may be possible to start a further characterization of cheeses in some countries.

Keywords: cheese, flavor, sensory

Practical Applications
This research shows the main flavor characteristics of certain types of cheeses manufactured in various countries. The information may be useful to cheese manufacturers, product developers, food scientists, cheese connoisseurs, and government officials to better understand the flavor classification of cheeses from various countries.

Introduction

Cheese is one of the most consumed foods in the world. It is believed that cheese flavor varies depending on a number of issues including milk source, fat content, pasteurization, microorganisms used for cheese making, aging, and other issues including cheese origin (i.e. country or locale within a country). In the United States (US) food, such as cheese must be labeled with its country of origin. In Europe, PDO (Protected Designation of Origin), PGI (Protected Geographical Indication), and TSG (Traditional Speciality Guaranteed) certificates have been issued to certain regions and foods to protect the authenticity and culture. For example, a PDO from Italy, "Provolone del Monaco" describes the flavor as sweet and buttery, with a light and pleasant spicy taste, which may change in intensity with the maturation of the cheese (Official Journal of the European Union, 20.6.2009). A PGI "Gouda Holland" states that the cheese is supposed to be aromatic, pleasant and mild to strong in flavor depending on the age (Official Journal of the European Union, 6.3.2008). Another PGI for German "Nieheimer Käse" (Official Journal of the European Union, 29.9.2009) says the cheese taste is pure, sharp, and spicy, with a touch of caraway, depending on the seasoning. Many of the sensory standards are vague (e.g. "pure", "aromatic") or give a range of potential flavors ("depending on seasoning", "mild to strong") that many cheeses could fall within the standard. Additionally, although "sweet" and "buttery" may be understood in a similar way by manufacturers and consumers, terms such as "spicy" and "sharp" may need further explanation. It may be necessary to add descriptors to some of the standards to better characterize the flavor properties the cheeses may have, but only if cheeses have a consistent flavor.

Studies of products from varying countries have been used both to compare products and to develop lexicons for further comparison. Forty-two cheeses from 13 countries were characterized and clustered by Heisserer and Chambers (1993) who developed a lexicon for natural cheeses from those samples. In 2008 Talavera-Bianchi and Chambers described 65 Western European cheeses with the objective of providing an alternative simplified lexicon for cheese.

It is important to develop a wider perspective of foods' flavor characteristics available on different continents or from different countries on the same continent. For example, as trade becomes ever more global, the flavors of a country or region become more widely available and may become "typical" in consumers eyes as they taste products from a certain area.

Apart from the already mentioned cheese lexicon development and descriptive studies, the sensory profiles of geographic origins of certain cheeses have been studied. For example the flavor of 20 Swiss cheeses from different countries was characterized by near-infrared spectroscopy and sensory analyses by Karoui and others in 2006. Italian cheese such as Reggianito Argentino was studied by Sihufe and others (2010) and sensory profiles for PDO Fiore Sardo cheese were developed by Scintu and others (2010). Drake and others (2008, 2009), Caspia and others (2006) and Young and others (2004) have studied various Cheddar cheeses flavor and preferences in the US, while Koppel and others (accepted for publication) described the flavor and acceptance of cheeses manufactured in Estonia.

The objectives of this study were: 1) to use existing data to group and compare a wide variety of cheeses from different countries, and 2) map flavor characteristics of various cheese subgroups.

Materials and Methods

Samples

Sensory data of cheeses published in prior studies were used in this analysis. Sample cheeses (n=152, Table 1a-e) were purchased and analyzed as described in previous research (Rétiveau and others 2005; Talavera-Bianchi and Chambers 2008; Chambers and others 2010; Koppel and others [accepted for publication]). Rétiveau and others (2005) purchased 43 cheese samples that varied in maturation time, milk source, region, and processing methods from the US and France. Talavera-Bianchi and Chambers (2008) purchased 65 European cheeses that varied in country of manufacture, fat content, milk source, and processing methods from Germany. Chambers and others (2010) described seven types of cheeses which were manufactured either from raw or pasteurized milk by different manufacturers in France. Koppel and others (accepted for publication) described the flavor and acceptance of 36 Estonian cheeses, varying in fat content, processing methods, and manufacturer.

For this analysis and graphing, the samples were coded according to the manufacturing country (first letter/letters: Austria – A, Belgium – B, Denmark – D, England – E, Estonia – Es, France – F, Germany – G, Greece – Gr, Holland – H, Ireland - Ir, Italy – I, Norway – N, Spain – Sp, Switzerland – S, Sweden – Sw) and consecutive numbers (Table 1a-e).

Sensory Analysis

All of the studies used panels from the same laboratory trained by the same procedures; many panelists were common among the studies. The highly trained and experienced panelists had completed 120h descriptive sensory analysis training and had experience testing various dairy products. In all of the studies panelists received 2h - 2weeks of orientation concerning the specific cheeses to be tested. Koppel and others (accepted for publication) tested the samples in three repetitions. Three of the studies (Rétiveau and others 2005; Talavera-Bianchi and Chambers 2008; Chambers and others 2010) used a modification of flavor profiling from that described by Keane (1992). The eighteen attributes included in data analysis were evaluated in at least three of the four studies. The attributes included dairy notes (buttery, cooked milk, dairy fat, dairy sour, dairy sweet), animal notes (butyric acid, goaty), fungal (musty/earthy, moldy), feeling attributes (astringent, pungent, sharp, biting), fundamental tastes (bitter, sour, salty, sweet), and other attributes (nutty). Because of the evaluation methods used, it was reasonable to assume that if the term was not used in a study, it scored "0" for the cheeses in that study. In all of the studies the attributes were evaluated on a 15-point scale, where the range 0 - 4.5 indicated low, 5.0 – 9.5 moderate, and 10.0 – 15.0 strong flavor.

Data analysis

The sensory data from the cheese samples were analyzed using Principal Component Analysis (PCA) and K-means clustering to examine the overall groupings based on sensory properties. In addition to that overall sensory clustering the samples were sorted according to texture type (soft, semi-soft and semi-hard, and hard), and milk source. XL Stat (AddInSoft 2010, New York, NY, USA) was used to conduct the data analysis.

Results and Discussion

Overall Clustering Based on Sensory Properties

K-means clustering showed four major clusters among the samples (Fig. 1). PCA indicated these clusters carried independent flavor properties. Principal component (PC) 1 (40.22% variation) showed positive loadings on salty, sour, astringent, biting, and pungent and negative loadings for sweet and nutty, and cooked milk flavor. PC2 (15.50% variation) showed positive loadings for buttery, dairy fat, and dairy sweet and negative loadings for sharpness in flavor.

Cluster 1 was formed from cheeses that were musty, moldy, sour, salty, and also buttery in their flavor. The cheeses were from Italy (n=1), Estonia (n=1), and France (n=27), and included surface-ripened cheeses that ranged from soft to semi-hard in texture.

Cluster 2 was composed of cheeses that were dairy sour, sour, salty and also carried some pungent, biting, and sharp properties. The cheeses in cluster 2 were from different countries: Italy (n=2), France (n=15), and Greece (n=1), and included cheeses varying in texture properties, milk source and processing methodology; the common characteristics among these samples seem to be volatile flavor and aroma properties, that may cause irritation sensations in the nasal cavity.

Cluster 3 included cheeses that had dairy flavor, such as cooked milk, dairy sweet, buttery, and dairy fat. This cluster was composed of 45 cheeses from France (n=18), Germany (n=5), Italy (n=5), Switzerland (n=4), Norway (n=3), Holland (n=3), Denmark (n=2), England (n=1), Belgium (n=1), Ireland (n=1), and Austria (n=1). As in cluster 2, these samples varied in texture properties, milk source and processing methodology.

Cluster 4 formed from cheeses that carried cooked milk and nutty flavors, but had a more “sharp” flavor than samples in cluster 3. This cluster was composed of 60 cheeses from Estonia (n=35), Italy (n=7), France (n=5), Switzerland (n=3), Spain (n=2), Germany (n=2), Denmark (n=2), Holland (n=2), England (n=1), and Austria (n=1). A major part of this cluster was composed of Estonian cheeses, which were described by Koppel and others (accepted for publication) as being mild-flavored and carrying mostly dairy properties. Most of the cheeses in cluster 4 were semi-soft, semi-hard, or hard in texture and manufactured without surface ripening or veining.

Cluster analysis indicated French cheeses were dominant in cluster 1 and 2 (Table 1a-e). Clusters 3 and 4 had more variation country-wise in their samples (samples from 11 and 10 countries, respectively). French and Italian cheeses seem most variable in flavor properties, as those cheeses were present in all clusters.

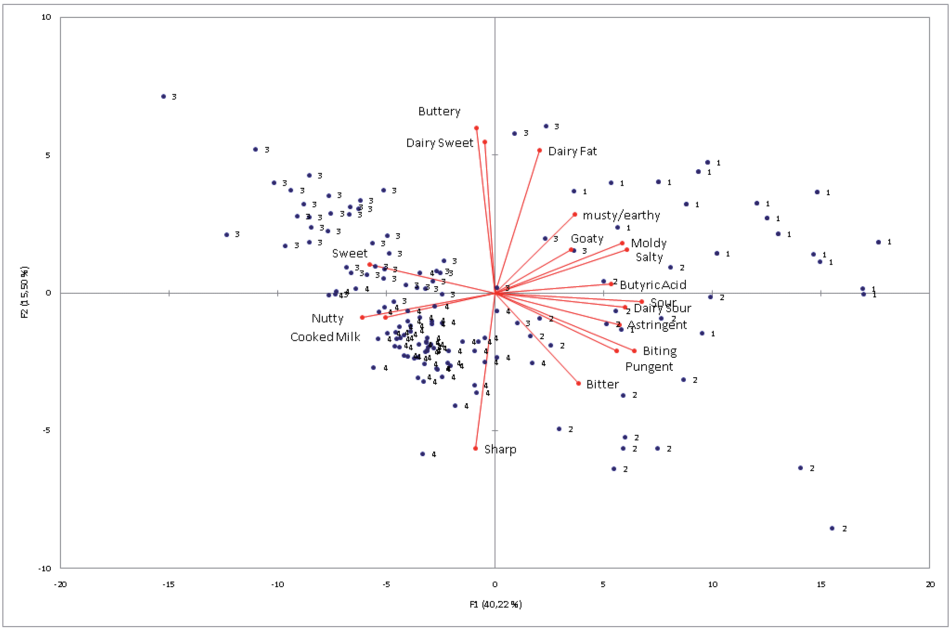

Figure 1. PCA of cheese data. Numbers 1-4 represent cheeses in clusters 1-4.

The same types of cheeses were not always in the same cluster. For example, Samples 139F (in cluster 3) and 140F (in cluster 1) were both Brie cheeses. Sample 139F was manufactured from pasteurized milk and sample 140F from raw milk. Clusters 3 and 1 positioned next to each other on the PCA map, while the two samples differed in dairy flavor, goaty, and pungent sensations. Sample 9F (cluster 3), 10F (cluster 1), 11F (cluster 2), and 12F (cluster 2) were also Brie cheeses. Sample 9F positioned close to sample 139F and sample 10F close to 140F on Fig 1, suggesting similarity in flavor characteristics. Sample 11F and 12F were more pronounced in the sharp attribute.

Samples 1F and 2F present another example. Both of these samples were "Bleu d´Auvergne" cheese, however, sample 1F clustered into cluster 1 (higher in buttery and dairy sweet) and 2F (higher in sharpness) into cluster 2.

There were seven Camembert cheese samples among the data set: 6F, 47F, and 48F (cluster 3), 4F and 5F (cluster 1), 7F and 8F (cluster 2). The samples in cluster 2 were lower in musty/earthy and buttery notes, while samples in cluster 1 were higher in goaty notes and saltiness. Samples 6F, 47F, and 48F carried cooked milk flavor and sweet taste.

Two examples can be given of samples not manufactured in France. The first example includes Edam cheese samples 53H (cluster 3), 124Es and 132Es (cluster 4). These samples were similar in flavor. The Estonian samples were higher in sharp notes, while the cheese from Holland was saltier and sweeter and had more dairy fat flavor. The other example also involves Estonian (103Es and 119 Es in cluster 4) and Dutch (60H in cluster3) samples of Gouda cheeses. Sample 60H (cluster 3) was higher in buttery and dairy fat flavor intensity, and samples 103Es and 119Es were higher in biting and sharp attributes.

There are also examples of cheeses which were studied at different times or several samples within a study, but resulted in the same cluster, and thus were more uniform in their flavor variation. For example, Chévre cheese samples 29F, 30F, 149F, and 150F (cluster 1) were very similar in their flavor characteristics. Similar examples were the Manchego cheeses, samples 72Sp and 73Sp (cluster 4) and Mozzarella cheese samples 79I and 80I (cluster 3). Another example is samples 55S and 56S, which were both Emmental-type cheeses from Switzerland. Both of these samples clustered into cluster 4 and according to the PCA map the samples were located close to each other. On the PCA map it is clear that the main flavor attributes (sweetness and nuttiness) are characteristic to these samples. These two attributes were reported as characteristic of Swiss cheese by Clark and others (2009).

These results suggest that although the cheeses often have differences in flavor strength and in some cases a key characteristic, such as sharpness, the main characteristics of cheeses of the same type remain the same.

PCA of Cheeses in Subgroups

Cheese Manufactured from Cow Milk

Cheese samples manufactured from cow milk (n=118) were from Austria (n=1), Denmark (n=4), England (n=2), Estonia (n=36), France (n=46), Germany (n=4), Holland (n=5), Ireland (n=1), Italy (n=10), Norway (n=2), and Switzerland (n=6). PC1 explained 46.65% of the variation and the contributing attributes were sour, dairy sour, salty, moldy, biting, nutty, sweet, and cooked milk (Fig. 2). PC2 explained 15.57% of the variation between samples and the differentiating attributes were buttery, dairy fat, dairy sweet, and sharp. Overall distribution of the attributes on Fig. 2 is similar to Fig. 1.

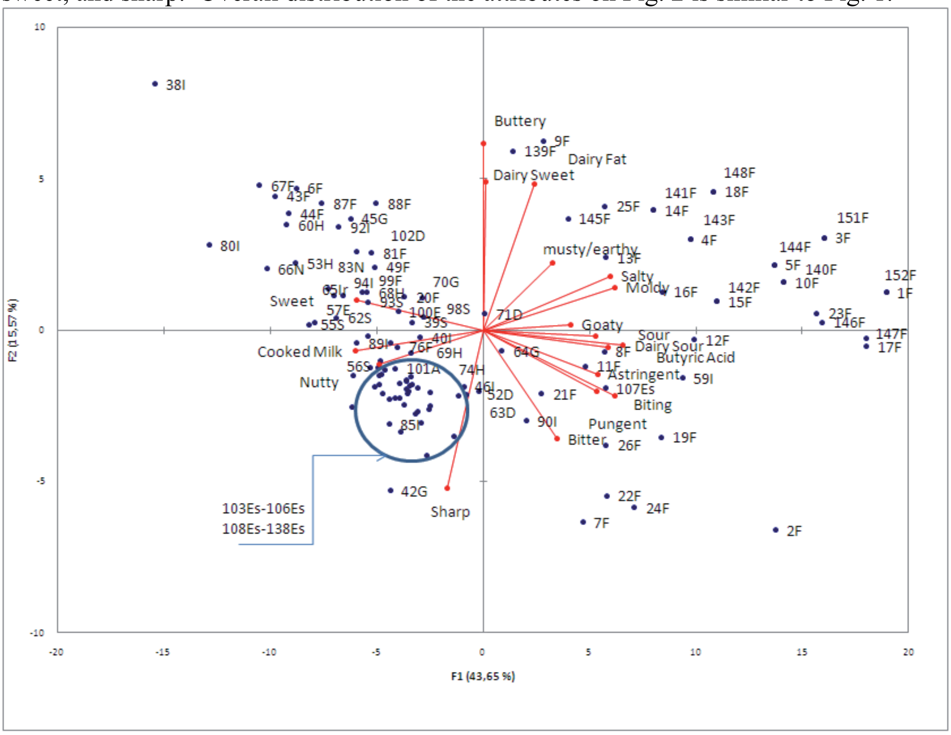

Fig. 2. PCA of cheeses manufactured from cow milk.

Goat, Ewe, Sheep, and Buffalo Milk Cheese

Eighteen of the 28 cheese samples manufactured from goat, goat and sheep, or goat and cow milk were from France. Other samples were manufactured in Norway (n=1), Greece (n=1), Spain (n=2), and Italy (n=6). PC1 (36.08% variation) explained the cooked milk and nutty aromatics versus the salty, pungent, sour, dairy sour, biting and astringent flavors (Fig. 3). PC2 (18.00% variation) explained the buttery, dairy fat dairy sweet, musty/earthy, and goaty flavors versus the sharp notes. The main characteristics differentiating the cheeses were the same as in earlier analyses for cow-milk cheeses and overall mapping of cheeses, except for the addition of a higher goaty flavor. Four Chévre cheeses (29F, 30F, 149F, 150F) grouped around the goaty and musty/earthy attribute, these samples were scored highest in the goaty attribute within the sample set.

The outlier among these samples was sample 37F, which was a Roquefort cheese, strong in sharp, biting, pungent, dairy sour, and salty attributes.

Similar flavor profiles were found among four cheese samples: 48F (Camembert), 54N (Ekte Gjetost), 77I (Mona Lisa), and 78F (Mont Roc). These cheeses had low to moderate range intensities of salty (4.0-6.0), buttery (4.5-6.5), and dairy fat flavors (7.00), and low range intensities for cooked milk (2.0-3.5), nutty (1.5-3.0), astringent (2.0), biting (0-1.0), bitter (2.0), and sour (1.5-2.0) attributes.

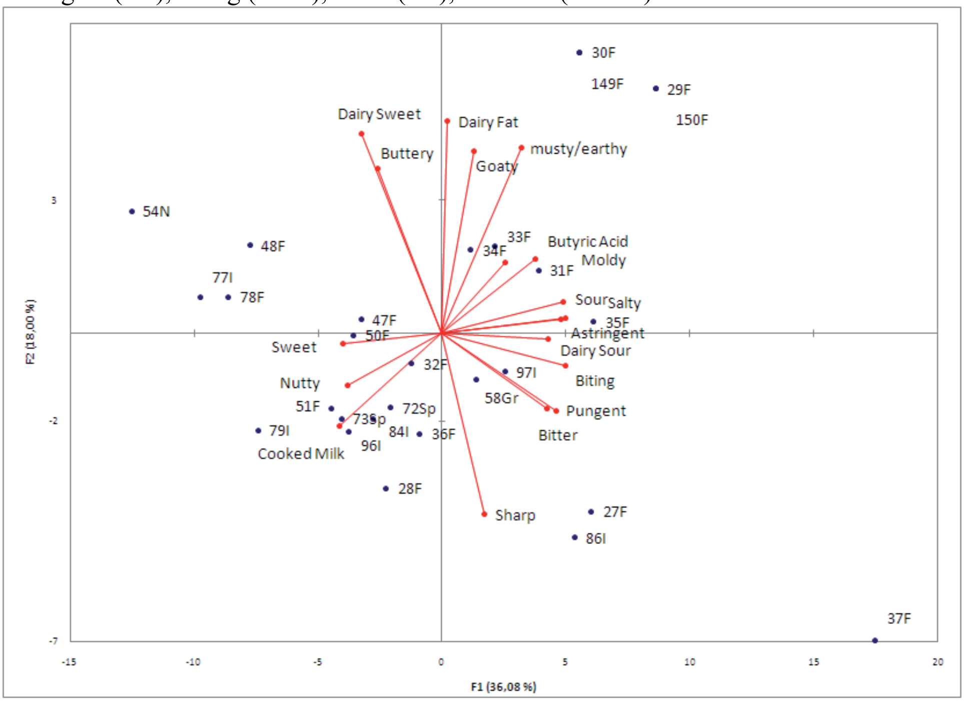

Figure 3. PCA of cheeses manufactured from goat, ewe, buffalo, and sheep milk.

Hard-Textured Cheese

Twenty samples of hard-texture cheeses manufactured from cow, goat, and sheep milk included samples from France (n=1), Norway (n=2), Switzerland (n=5), Italy (n=7), Spain (n=2), Austria (n=1), England (n=1), and Holland (n=1). PC1 (42.72% variation) was explained by variation in dairy sweet, buttery, dairy fat, astringent, pungent, sharp, and biting flavors. PC2 (11.77% variation) was characterized by nutty, moldy, and sour flavors (Fig. 4).

Three samples (90I, 54N, and 86I) exhibited somewhat stronger flavor intensities than the rest of the samples. These were Ekte Gjetost sample 54N, that carried higher dairy flavor intensities, Ricotta Salata cheese sample 90I was more pronounced in goaty and dairy sour flavor and sour taste, and sample 86I, Pecorino Sardo cheese, low in dairy flavor intensities, more pronounced in saltiness and sharpness.

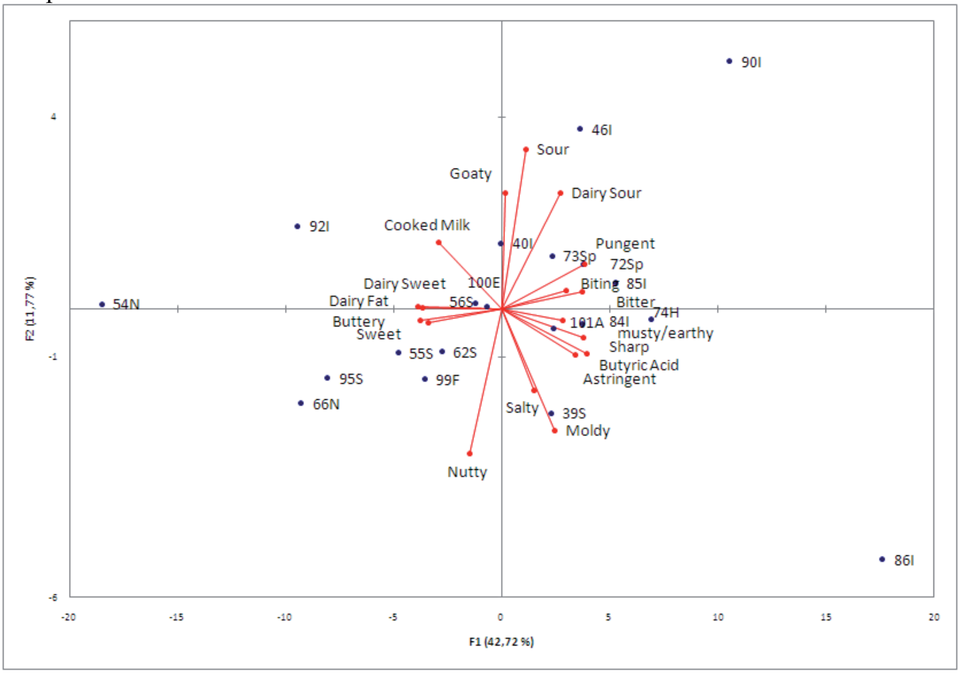

Figure 4. PCA of hard-texture cheeses.

Soft-Textured Cheese

Sixty-two soft-textured cheeses were manufactured in Austria (n=1), Belgium (n=1), Denmark (n=1), France (n=50), Germany (n=2), Greece (n=1), Italy (n=5), and Switzerland (n=1). The explanatory attributes were similar to the overall cheese flavor map (Fig. 1) and the cow milk cheeses map (Fig. 2). PC1 (41.77% variation) differentiated the samples according to cooked milk, sweet, astringent, biting, moldy, salty, and sour attributes (Fig. 5). PC2 (17.09% variation) differentiated the samples according to dairy fat, dairy sweet, butter, musty/earthy, and sharp flavors. Eleven of the 12 cheeses (except for sample 59I) that were not manufactured in France were situated on the negative side of PC1 together with 16 of the 50 samples manufactured in France. These samples were more pronounced in cooked milk, nutty, and sweet flavors. According to this French soft cheeses are versatile in their flavor profiles.

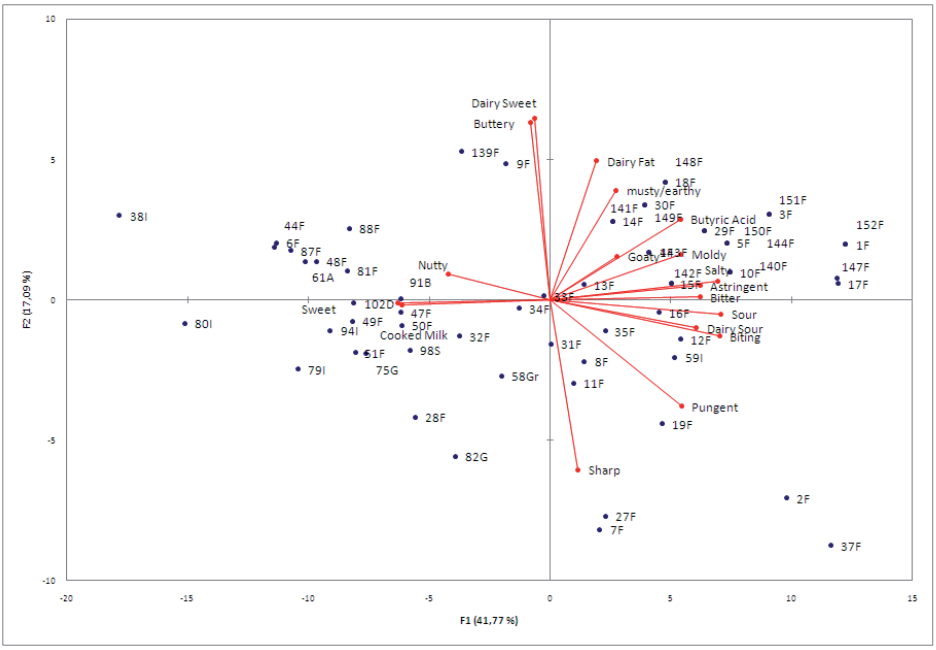

Figure 5. PCA of soft-texture cheeses.

Semi-Hard and Semi-Soft Cheeses

Sixty-eight samples of semi-hard and semi-soft textured cheeses were compared. Most cheeses were manufactured from cow-milk, except for samples 77I (sheep), 36F (ewe), 96I and 97I (cow and sheep). The samples were manufactured in Denmark (n=3), England (n=1), Estonia (n=36), France (n=13), Germany (n=4), Holland (n=4), Ireland (n=1), Italy (n=4), Norway (n=1), and Switzerland (n=1). PC1 explained 34.16%, and PC2 16.79% of the variation between samples (Fig. 6). PC1 differentiated between the samples according to butyric acid, biting, pungent, sweet, and moldy flavors. PC2 divided the samples according to cooked milk, dairy fat, astringent, salty, and bitter attributes.

According to Fig. 6 the Estonian cheese samples differed from the rest of the semi-hard and semi-soft cheese samples in the cooked milk, bitter, and astringent attributes.

The two Saint-Nectaire cheese samples 146F and 23F were situated apart from the other samples as the flavor profiles indicated more intense butyric acid, musty, and moldy flavors. Samples 24F, 25F, and 145F were also Saint-Nectaire cheeses, which were less intense in these flavors, but saltier.

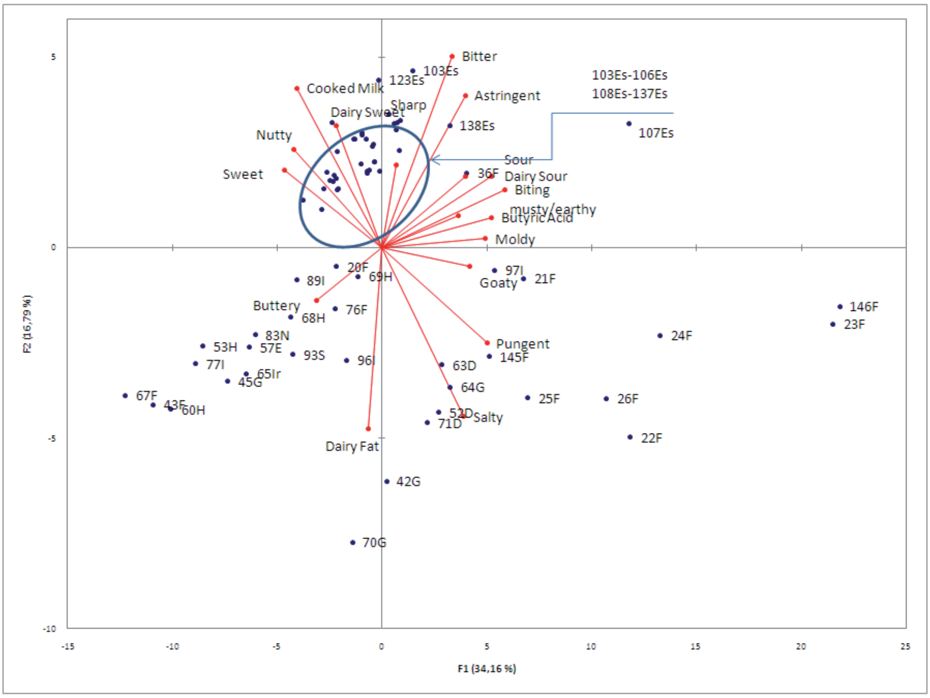

Figure 6. PCA of semi-hard and semi-soft texture cheeses.

Conclusions

The main flavor characteristics of the cheeses tested were salty, sweet, sour, astringent, biting, pungent, sharp, nutty, musty/earthy, dairy fat, buttery, and dairy sweet. The cluster analysis divided the cheeses into four major clusters, although smaller subclusters exist. Italian cheeses varied considerably, but French cheeses seemed to have one of two common flavor themes as they were dominant in two of the four clusters.

Within cheese subgroups, in the semi-hard and semi-soft cheeses subgroup sample groupings by countries could be observed. Similar discriminating attributes could be observed for overall cheese mapping, cow milk cheeses, other than cow milk cheeses, and soft-textured cheeses. Although the overall sample set was fairly large (n=152), for some countries or cheese subgroupings further studies may be necessary to characterize cheese flavor properties.

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Table 1a. Sample codes, names, country of manufacture, milk source, ripening technology, texture, and cluster.

Code	Name	Country	Milk source	Surface ripened /veined	Texture	Cluste r
1F	Bleu d'Auvergne	France	Cow	Yes	Soft	1
2F	Bleu d'Auvergne	France	Cow	Yes	Soft	2
3F	Bleu de Bresse	France	Cow	Yes	Soft	1
4F	Camembert	France	Cow	Yes	Soft	1
5F	Camembert	France	Cow	Yes	Soft	1
6F	Camembert	France	Cow	Yes	Soft	3
7F	Camembert	France	Cow	Yes	Soft	2
8F	Camembert	France	Cow	Yes	Soft	2
9F	Brie	France	Cow	Yes	Soft	3
10F	Brie	France	Cow	Yes	Soft	1
11F	Brie	France	Cow	Yes	Soft	2
12F	Brie	France	Cow	Yes	Soft	2
13F	Brie de Meaux	France	Cow	Yes	Soft	1
14F	Coulommier	France	Cow	Yes	Soft	1
15F	Coulommier	France	Cow	Yes	Soft	1
16F	Saint André	France	Cow	Yes	Soft	2
17F	Munster	France	Cow	No	Soft	1
18F	Munster	France	Cow	No	Soft	1
19F	Munster	France	Cow	No	Soft	2
20F	Port Salut	France	Cow	No	Semi-Hard	4
21F	Raclette	France	Cow	No	Semi-soft	2
22F	Reblochon	France	Cow	Yes	Semi-soft	2
23F	Saint Nectaire	France	Cow	Yes	Semi-Hard	1
24F	Saint Nectaire	France	Cow	Yes	Semi-Hard	2
25F	Saint Nectaire	France	Cow	Yes	Semi-Hard	1
26F	Morbier	France	Cow	Yes	Semi-Hard	2
27F	Crottin de Chavignol	France	Goat	Yes	Soft	2
28F	Chavrie	France	Goat	N/A	Soft	4
29F	Chèvre	France	Goat	N/A	Soft	1
30F	Chèvre	France	Goat	N/A	Soft	1
31F	Valençais	France	Goat	Yes	Soft	2
32F	Chabis	France	Goat	N/A	Soft	4
33F	Gatiotin	France	Goat	Yes	Soft	3
34F	Gatiotin	France	Goat	Yes	Soft	3
35F	Ossau Iraty	France	Ewe	N/A	Soft	2
36F	Petit Basque	France	Ewe	N/A	Semi-Soft	4

Samples 1F-36F from Rétiveau and others 2005.N/A – not available.

Table 1b. Sample codes, names, country of manufacture, milk source, ripening technology, texture, and cluster.

Code	Name	Country	Milk source	Surface ripened /veined	Texture	Cluster
37F	Roquefort	France	Ewe	Yes	Soft	2
38I	Annabella	Italy	Cow	No	Soft	3
39S	Appenzeller	Switzerland	Cow	No	Hard	3
40I	Asiago Fresco	Italy	Cow	No	Hard	4
41G	Bad Aiblinger	Germany	N/A	N/A	N/A	3
42G	Bauernhandkäse	Germany	Cow	Yes	Semi-soft	4
43F	Bonbel	France	Cow	No	Semi-soft	3
44F	Brie	France	Cow	Yes	Soft	3
45G	Butterkäse	Germany	Cow	No	Semi-soft	3
46I	Caciocavallo	Italy	Cow	No	Hard	4
47F	Camembert	France	Goat	Yes	Soft	3
48F	Camembert	France	Goat & Sheep	Yes	Soft	3
49F	Camembert de Normandie	France	Cow	Yes	Soft	3
50F	Chevrochon	France	Goat	Yes	Soft	3
51F	Corse Brin d' Amour	France	Goat & Sheep	No	Soft	3
52D	Danbo Delight	Denmark	Cow	No	Semi-soft	4
53H	Edam	Holland	Cow	No	Semi-hard	3
54N	Ekte Gjetost	Norway	Goat&Cow	No	Hard	3
55S	Emmentaler	Switzerland	Cow	No	Hard	4
56S	Emmentaler (Felsenkeller)	Switzerland	Cow	No	Hard	4
57E	Farmhouse Cheddar	England	Cow	No	Semi-Hard	4
58Gr	Feta	Greece	Sheep	No	Soft	2
59I	Gorgonzola	Italy	Cow	Yes	Soft	1
60H	Gouda Jung	Holland	Cow	No	Semi-Hard	3
61A	Graf Görtz	Austria	N/A	No	Soft	3
62S	Gruyère	Switzerland	Cow	No	Hard	4
63D	Havarti	Denmark	Cow	No	Semi-soft	4
64G	Hirtenkäse Natur	Germany	Cow	No	Semi-soft	3
65Ir	Irish Cheddar	Ireland	Cow	No	Semi-hard	3
66N	Jarlsberg	Norway	Cow	No	Hard	3
67F	Le Brin	France	Cow	Yes	Semi-soft	3
68H	Leerdamer	Holland	Cow	No	Semi-hard	3
69H	Leerdamer Light	Holland	Cow	No	Semi-hard	4
70G	Limburger	Germany	Cow	Yes	Semi-soft	3

Sample 37F from Rétiveau and others 2005; Samples 38I-70G from Talavera-Bianchi and Chambers 2008.N/A – not available.

Table 1c. Sample codes, names, country of manufacture, milk source, ripening technology, texture, and cluster.

Code	Name	Country	Milk source	Surface ripened /veined	Texture	Cluster
71D	Luxus Danbo Bauernhof	Denmark	Cow	No	Semi-hard	3
72Sp	Manchego (3 Months)	Spain	Sheep	Yes	Hard	4
73Sp	Manchego (6 Months)	Spain	Sheep	Yes	Hard	4
74H	Mei Klockje	Holland	Cow	No	Hard	4
75G	Miesbacher	Germany	N/A	N/A	Soft	3
76F	Mimolette Jung	France	Cow	No	Semi-Hard	4
77I	Mona Lisa	Italy	Sheep	No	Semi-hard	3
78F	Mont Roc	France	Cow & Sheep	N/A	N/A	3
79I	Mozzarella	Italy	Buffalo	No	Soft	3
80I	Mozzarella	Italy	Cow	No	Soft	3
81F	Munster	France	Cow	No	Soft	3
82G	Mutters Sorte	Germany	N/A	Yes	Soft	4
83N	Norvegia	Norway	Cow	No	Semi-Hard	3
84I	Pantaleo	Italy	Goat	No	Hard	4
85I	Parmesan	Italy	Cow	No	Hard	4
86I	Pecorino Sardo	Italy	Sheep	No	Hard	2
87F	Peyrigoux	France	Cow		Soft	3
88F	Pierre Robert	France	Cow	Yes	Soft	3
89I	Provolone Auricchio	Italy	Cow	No	Semi-hard	4
90I	Ricotta Salata	Italy	Cow	No	Hard	4
91B	Saint Feuillen	Belgium	.	No	Soft	3
92I	San Bernardo Dolce	Italy	Cow	No	Hard	3
93S	Santenberger	Switzerland	Cow	No	Semi-hard	3
94I	Scamorza Smoked	Italy	Cow	No	Soft	3
95S	St. Galler	Switzerland	.	No	Hard	3
96I	Testun al Barolo	Italy	Cow & Sheep	No	Semi-Hard	4
97I	Testun di Pecora	Italy	Cow & Sheep	No	Semi-hard	2
98S	Tête de Moine	Switzerland	Cow	Yes	Soft	3
99F	Tomme de Fedou	France	Cow	Yes	Hard	3
100E	Top Hat Cheddar	England	Cow	No	Hard	3
101A	Tyroler	Austria	Cow	No	Hard	4
102D	White Castello	Denmark	Cow	Yes	Soft	3

Samples 71D-102D from Talavera-Bianchi and Chambers 2008. N/A – not available.

Table 1d. Sample codes, names, country of manufacture, milk source, ripening technology, texture, and cluster.

Code	Name	Country	Milk source	Surface ripened /veined	Texture	Cluster
103Es	Gouda Black Label	Estonia	cow	No	Semi-Soft	4
104Es	Saare Leet Juust	Estonia	cow	No	Semi-Soft	4
105Es	Naeru Juust	Estonia	cow	No	Semi-Soft	4
106Es	Võru Juust Edam	Estonia	cow	No	Semi-Soft	4
107Es	Bret Blue	Estonia	cow	Yes	Semi-Soft	1
108Es	Põltsamaa Eesti Juust	Estonia	cow	No	Semi-Soft	4
109Es	Kostroma Juust	Estonia	cow	No	Semi-Soft	4
110Es	Eesti Juust Light	Estonia	cow	No	Semi-Soft	4
111Es	Südamejuust	Estonia	cow	No	Semi-Soft	4
112Es	Dr Hellus juust	Estonia	cow	No	Semi-Soft	4
113Es	Hiirte Juust	Estonia	cow	No	Semi-Soft	4
114Es	Köömne juust	Estonia	cow	No	Semi-Soft	4
115Es	Atleet	Estonia	cow	No	Semi-Soft	4
116Es	Eesti Juust Originaal	Estonia	cow	No	Semi-Soft	4
117Es	Hea Juust	Estonia	cow	No	Semi-Soft	4
118Es	Eesti Juust	Estonia	cow	No	Semi-Soft	4
119Es	Gouda Red Label	Estonia	cow	No	Semi-Soft	4
120Es	Saare Light Juust	Estonia	cow	No	Semi-Soft	4
121Es	Kadaka juust	Estonia	cow	No	Semi-Soft	4
122Es	Võru Juust Havarti	Estonia	cow	No	Semi-Soft	4
123Es	Ekstra Juust	Estonia	cow	No	Semi-Soft	4
124Es	Edam	Estonia	cow	No	Semi-Soft	4
125Es	Eesti Kuldne Juust	Estonia	cow	No	Semi-Soft	4
126Es	Hollandi	Estonia	cow	No	Semi-Soft	4

Samples 103Es-126Es from Koppel and others [accepted for publication].

Table 1e. Sample codes, names, country of manufacture, milk source, ripening technology, texture, and cluster.

Code	Name	Country	Milk source	Surface ripened /veined	Texture	Cluster
127Es	Atleet Light	Estonia	cow	No	Semi-Soft	4
128Es	Hollandi Leibjuust	Estonia	cow	No	Semi-Soft	4
129Es	Eesti Juust	Estonia	cow	No	Semi-Soft	4
130Es	Oma Juust	Estonia	cow	No	Semi-Soft	4
131Es	Lepasuitsu Eesti Juust	Estonia	cow	No	Semi-Soft	4
132Es	Edam Juust	Estonia	cow	No	Semi-Soft	4
133Es	Põltsamaa Eesti Light Juust	Estonia	cow	No	Semi-Soft	4
134Es	Estman	Estonia	cow	No	Semi-Soft	4
135Es	Hollandi Leibjuust	Estonia	cow	No	Semi-Soft	4
136Es	Mirjami juust	Estonia	cow	No	Semi-Soft	4
137Es	Vene Juust	Estonia	cow	No	Semi-Soft	4
138Es	Pühajärve Juust	Estonia	cow	No	Semi-Soft	4
139F	Brie P	France	cow	Yes	Soft	3
140F	Brie R	France	cow	Yes	Soft	1
141F	Coulommier P	France	cow	Yes	Soft	1
142F	Coulommier R	France	cow	Yes	Soft	1
143F	Camembert P	France	cow	Yes	Soft	1
144F	Camembert R	France	cow	Yes	Soft	1
145F	saint Nectaire P	France	cow	Yes	Semi-Hard	1
146F	Saint Nectaire R	France	cow	Yes	Semi-Hard	1
147F	Muenster P	France	cow	No	Soft	1
148F	Muenster R	France	cow	No	Soft	1
149F	Chevre P	France	goat	Yes	Soft	1
150F	chevre R	France	goat	Yes	Soft	1
151F	Bleu cheese P	France	cow	Yes	Soft	1
152F	Bleu cheese R	France	cow	Yes	Soft	1

Samples 139F-152F from Chambers and others 2010; Samples 127Es-138Es from Koppel and others [accepted for publication].

Article VI

K. Koppel, E. Chambers IV, L. Vazquez-Araujo, L. Timberg, A. Carbonell-Barrachina, S. Suwonsichon. Pomegranate Juice Acceptance in Estonia, Spain, Thailand, and United States. Manuscript submitted.

Pomegranate Juice Acceptance in Estonia, Spain, Thailand, and United States

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Abstract

Five pomegranate juices were evaluated by consumers in Thailand, Estonia, Spain, and the United States of America (US) with the objective of studying whether different flavors were accepted in different countries. The juices were selected according to their flavor properties from a previous study on pomegranate juice (Koppel & Chambers, 2010). The consumers evaluated overall acceptability and flavor, sweet, sour, fruity, and pomegranate flavor liking. Also, Just About Right (JAR) questions were answered for the intensity of the same attributes. Forty-two statements concerning different attributes of the samples were evaluated using a check-all-that-apply format.

The results suggest Estonian, US, and Thai consumers liked sample B/B1 that was sweet, sour, and carried cranberry and grape or fruity flavors. Sample E, that was high in sweet aromatics, was also highly liked in all countries, but was checked as having "artificial taste" or "fruit flavored drink" by some consumers. Sample D, high in astringency, with fermented and metallic notes, was not liked in any country. Clustering showed some split opinions for several samples. The most important statements were related to purchase intent, health issues, product liking, and juice authenticity.

Keywords: pomegranate juice, acceptance, consumer, flavor

1. Introduction

In recent years the awareness of health benefits of pomegranate fruits and supplements from pomegranates has been increasing. Because of market demand, various products made from pomegranates have become available. Among others, pomegranate juice is a product which provides a simple and convenient way to consume biologically active nutrients.

Pomegranate juice has been studied for positive health effects for several years. A review by Viuda-Martos, Férnandez-López & Pérez-Álvarez (2010) presents recent research on chemical composition, bioactive compounds, impact on cardiovacular health, antitumoral properties etc. on pomegranates. Gasmi & Sanderson (2010) showed that punicic acid, which is present mainly in pomegranate seed oil, may have a role in the prevention of prostate cancer. Guo et al., (2008) reported that pomegranate juice leads to a reduction in systemic oxidative stress in a study conducted among elderly subjects. Rosenblat, Hayek, & Aviram (2006) reported positive health effects resulting from consumption of pomegranate juice by diabetic patients.

Some studies have recently concentrated on characterization of food flavors internationally. For example, green teas, the consumption of which is considered healthy and growing in popularity were studied for acceptance in three countries by Lee et al., (2010). While different flavors were preferred in different countries, bitterness was disliked everywhere. Another example from the drink category is a study conducted by Oupadissakoon, Chambers, & Chambers (2009), in which the sensory properties of ultra-high-temperature milks from different countries were compared. These authors reported that for this product production technology may have more impact on the product characteristics than local raw material quality. Neely, Lee, & Lee (2010) studied a soy-based extruded snack food with U.S. and Indian consumers and found that individual preferences were more important than cultural factors.

Previous studies on pomegranate juice have indicated that pomegranate juice flavor and aroma are not uniform characteristics by products. Koppel & Chambers (2010) studied the sensory characteristics of 33 different pomegranate juice brands that were acquired from several countries. As a result of the study the authors classified these juices into five different flavor clusters. In general, pomegranate flavor was described as sour, sweet, and having musty/earthy, fruity aromatics, astringent mouthfeel, and a combination of fruity and berry notes (grape, cranberry, cherry etc.), but also vegetable notes such as beet and carrot. Later, Vázquez-Araújo et al., (2011) studied the differences between commercial and fresh pomegranate juice flavor and aroma; the volatiles were present in higher concentrations in the fresh juice than in the processed juices, which suggests that aromatics are being lost from processing, a challenge for industry. Calin-Sanchez et al., (2011) studied several cultivars of Spanish pomegranates and found that the presence of certain monoterpenes (such as α-pinene) was related to high acceptance by Spanish consumers and the presence of aldehydes (such as hexanal) resulted in lower.

Consumer satisfaction has been studied with various blended juices, but not with pomegranate juice alone. Vázquez-Araújo, Chambers, Adhikari, & Carbonell-Barrachina (2010) studied consumer liking of pomegranate juice mixed with other juices and found juice mixtures which contained 90% pomegranate and 10% blackberry or raspberry juice were highly liked. The liking of mixed fresh and healthy juices was also studied by Endrizzi, Pirretti, Calo, & Gasperia (2009). Pomegranate, pineapple, apple, orange, and blood orange juices were mixed with strawberry, raspberry, blackberry, red currant, and bluebeerry juices. The consumers disliked mixtures with pomegranate juice and liked pineapple and blood orange mixes best.

The objective of this study was to compare consumer acceptance and attitudes towards five different pomegranate juices, in four different countries: Thailand, Estonia, Spain, and the United States of America (US).

2. Materials and Methods

2.1 Samples

Six samples, which represented the five flavor clusters reported by Koppel & Chambers (2010) were acquired from Estonia, Spain, US, and Thailand. The information concerning the samples is given in Table 1. Four of the samples (B, C, D, and E) had been used in the study by Koppel & Chambers (2010). One sample (B), was delayed in customs when shipping to Thailand and a locally available sample representing the same cluster was substituted with a sample referred to as B1. Two of the samples (A, B1) were used to represent clusters from the earlier study based on cluster descriptors given by Koppel & Chambers (2010), but were not part of that study. Sample E was a pomegranate juice concentrate, which was diluted prior to testing with purified water 1:3 (concentrated juice : water ratio). All samples were purchased from grocery stores or ordered in bulk except for sample C, which was generously provided by Granadas de Elche, located in Alicante, Spain. All of the samples were stored, as indicated on the packaging, at room temperature until testing and sent to each of the participating countries by postal services.

Table 1. Samples tested and their origin.

Sample	Cluster*	Countries tested in	Country of origin	Country acquired from
A**	4	Estonia, US, Spain, Thailand	Azerbaijan	Estonia
B	2	Estonia, US, Spain	N/A	US
B1**	2	Thailand	N/A	Thailand
C	1	Estonia, US, Spain, Thailand	Spain	Spain
D	3	Estonia, US, Spain, Thailand	N/A	US
E	5	Estonia, US, Spain, Thailand	N/A	US

*according to descriptions by Koppel and Chambers 2010.

**Juice not studied by Koppel and Chambers 2010

2.2 Descriptive Sensory Analysis

The flavor profile of the samples was determined using six highly trained panelists. The same procedure was used in descriptive profiling as described by Koppel & Chambers (2010). All of the samples (A, B, B1, C, D, and E) were tested both at room temperature (20-22°C) and cooled (5-7°C) to confirm presence of key flavor attributes at both temperatures as the juice was served cooled (5-7°C) to the consumers.

2.3 Consumer Study

Consumer acceptances were studied in Estonia, US, Spain, and Thailand. The studies took place in December 2010 in US and Estonia, in January 2011 in Spain, and in February 2011 in Thailand. Approximately one hundred consumers, with a ratio of 60:40 women and men, respectively, were recruited in each country for a central location test.

All of the participating consumers were recruited via e-mails and fliers in all participating countries. The consumers had to complete a screener stating their gender, age, and diet restrictions or allergies. The consumers were asked about juice consumption frequency and willingness to taste pomegranate juice from a selection of juices. Consumers, who stated they were 18-64 years old, drank any kind of juice at least two times per week, had no diet restrictions or allergies, and were willing to taste pomegranate juice, were recruited for testing.

The ballots, screeners, and demographic questionnaires were translated from English to Estonian, Spanish, and Thai and then back to English to confirm no major misinterpretations took place during the translation process.

From the day before testing the samples were cooled and stored in a refrigerator (3-5°C). The samples were poured into disposable plastic cups approximately 1-1.5 hours before testing, and just before serving were stirred using a plastic disposable spoon. The samples were served (appr at 5-7°C) in a randomized order. The consumers were asked to clean the palate with purified water and unsalted crackers after tasting a sample. The consumers had to complete a ballot and answer questions on a 9-point liking scale where 1 = dislike extremely and 9 = like extremely. Questions included overall, flavor, sweet taste, sour taste, fruity flavor, pomegranate flavor, and aftertaste liking. The consumers were also asked about flavor, sweetness, sourness, fruitiness, pomegranate flavor, and aftertaste intensities on a 9-point JAR scale where 1 represented "extremely weak", 5 "Just about right", and 9 "extremely strong". In conjunction with the question about pomegranate flavor liking and intensity it was possible for the consumers to check a box if they did not know what pomegranate flavor is supposed to taste like and also a box if they did not think the served tasted pomegranate-like. This was applied to the first juice sample in all countries.

The last question for each sample was a CATA question. The consumers were asked to read through all of the choices that concerned the appearance or mouthfeel of the juice (pulpy, smooth, mouthpuckering/astringent), different flavor attributes (floral, wine-like flavor, fruity like a grape, fruity like a raisin, fruity like cranberry, fruity like a cherry, candy-like flavor, pleasant flavor, fruity like a berry, musty like a beet, fermented flavor), attitudes toward the juice tasted (nasty flavor, for adults, for kids, for the entire family, fruit juice with other added ingredients, 100% fruit juice, fruit-flavored drink, I would consider buying this, I would drink every day, I would drink occasionally, I would drink at any time, I would drink when I want a snack, I would drink with meals, I have no interest in buying this, I would drink on special occasions, I would drink when I am thirsty, cheap, expensive, high in sugar, low in sugar, natural color, artificial color, familiar flavor, unfamiliar flavor, natural taste, artificial taste, healthy, unhealthy) and check the ones that applied for that sample.

After tasting all samples the consumers were asked to complete a demographic screener and answer questions on their gender, age, education level, and juice consumption habits.

2.4 Data Analysis

Acceptance data on samples B and B1 were considered as one sample as these samples represented the same flavor cluster. Consumer data were analysed using XL Stat version 2011.1.04 (XL Stat, New York, NY, US). Significant differences ($p=0.05$) were found using the Pearson coefficient between countries for samples and also between juices for a country. The consumers were clustered using K-means clustering according to flavor liking scores as descriptive sensory analysis also evaluated the flavor of the samples. Consumer cluster flavor likings were mapped with descriptive sensory analysis data added as supplemental variables using Principal Component Analysis (PCA). For just about right data, scores 6-9 were grouped as "too high" and scores 1-4 were grouped as "too low". The CATA question results were summarized and 15 most scored clauses in each country were used in PCA.

3. Results and Discussion

3.1 Descriptive data

All descriptive analysis attributes detected in each one of the samples are shown in Table 2. Sample A was higher in sour, astringent and dark-fruity attributes; sample B1 had cranberry, fruity and berry aromatics; sample B was high in cranberry and grape notes; sample C had some musty/earthy and beet notes and there was a chalky mouthfeel present; sample D was sour, astringent, bitter, but also carried fermented and metallic notes, and sample E was high in sweet overall, with cherry and candy-like notes present in addition to the sweet taste. The differences between scores at room temperature versus cold juices did not exceed 1 point for most attributes and therefore the consumer study was conducted using refrigerated juices to stimulate more accurately the way consumers drink juices.

3.2 Consumer study results

3.2.1 Acceptability and just-about-right scores within countries

In Estonia, sample B, which was high in berry flavor, was evaluated highest for all liking attributes (Table 3). Although sample B scored highest for liking, large percentages of consumers thought it was too high in overall flavor intensity (Table 4). Sample D, a sour, bitter, astringent, and metallic sample, was least liked and mean scores for all attributes ranged from 4.1-4.8. Aftertaste, flavor, and sourness were judged as too high and sweetness as too low in that sample by a large percentage of consumers. Pomegranate flavor was evaluated as not pleasant (mean score less than 5) for samples A, D, and E. Five Estonian consumers indicated they "don't know pomegranate flavor" and several thought individual samples did not taste like pomegranate juice (A=4, C=3, D=1, E=5).

In Spain sample C (sample C was of Spanish origin), characterized as musty, with beet flavor and sweet, was evaluated as best in all liking attributes (mean scores >5). Sample E, which was high in sweet, candy-like and cherry aromatics, received high scores in overall, flavor, sweet, sour, and aftertaste liking. Although samples D and A carried some grape and fruity flavors, these samples were also sour, astringent, and bitter, and were least liked (mean scores of 2.8-3.2 and 3.3-3.8, respectively). Most Spanish consumers found the flavor and sour taste intensities of samples D and A as too high and sweet taste and pomegranate flavor intensities as too low (Table 4). No Spanish consumers marked the box "don't know pomegranate flavor", but 14 marked the box "does not taste like pomegranate juice" (A=4, B=1, C=1, D=4, E=4).

In the US samples B and E were liked best and differences in attributes existed only in pomegranate flavor liking. A large percentage of consumers evaluated sample B as too high in flavor intensity and sample E as too high in sweet taste intensity (Table 4). Samples C and D were evaluated as unpleasant (mean scores for all evaluated attributes less than 5). Pomegranate flavor liking of samples E, C, and D mean scores showed pomegranate flavor of these samples was not liked or was not considered pomegranate-like. Fourteen US consumers said they did not know how pomegranate is supposed to taste like and three consumers noted the samples don' t taste like pomegranate juices (A=1, C=1, E=1). This indicates US consumers may be more aware than the consumers in other countries tested of the variations present within pomegranate juice flavors.

Table 2. Flavor profiles of the juices tested.

Sample	A		B1		B		C		D		E	
Attribute	room	cold	room	cold	room	cold	room	cold	room	cold	room	cold
Sour	6.0	6.0	4.0	4.0	4.0	4.0	3.5	3.5	4.5	6.5	3.5	3.5
Sweet	3.0	3.0	2.5	3.5	2.0	3.0	3.0	3.0	3.5	3.5	5.0	5.0
Cranberry	ND	ND	4.5	4.0	7.0	7.0	ND	ND	5.0	5.0	ND	ND
Grape*	ND	3.0	6.5	5.5	6.5	6.5	2.0	2.0	ND	ND	2.5	0.0
Metallic	ND	ND	ND	ND	2.0	2.0	2.0	2.0	4.0	4.0	ND	ND
Beet	ND	ND	ND	ND	2.5	2.5	4.0	3.5	2.0	2.0	ND	ND
Carrot	ND	ND	ND	ND	2.0	2.0	4.0	3.0	ND	ND	ND	ND
Musty/ earthy	3.0	4.0	4.0	3.5	4.0	3.0	5.5	5.5	ND	ND	ND	ND
Fruity-dark	5.5	4.5	ND	ND	3.0	3.0	4.5	4.0	3.5	3.5	ND	ND
Sweet overall	4.5	4.5	4.0	4.5	4.0	4.0	4.5	4.5	4.0	4.0	8.0	8.5
Sour2	4.5	4.5	ND	ND	3.5	3.5	3.5	4.0	4.0	4.0	ND	ND
Bitter	4.0	4.0	4.5	4.0	4.5	4.5	4.5	4.5	5.5	5.0	3.5	3.5
Astringent	5.0	5.0	3.5	3.5	3.5	3.5	4.0	4.0	6.5	7.0	3.0	2.5
Toothetch	2.5	2.5	3.0	3.0	3.0	3.0	3.5	3.5	5.0	5.0	2.0	2.0
Metallic mf	ND	ND	ND	ND	3.0	3.0	4.5	4.5	5.0	5.0	ND	ND
Fruity	ND	ND	5.5	5.5	ND	ND	ND	ND	3.5	3.5	4.0	5.0
Floral	ND	ND	ND	ND	ND	ND	ND	ND	2.0	2.0	ND	ND
Fermented	ND	ND	ND	ND	ND	ND	ND	ND	5.0	5.0	ND	ND
Bitter2	ND	ND	ND	ND	ND	ND	ND	ND	4.5	4.5	ND	ND
Astringent 2	ND	ND	ND	ND	ND	ND	ND	ND	6.0	6.0	ND	ND
Candy-like	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.0	8.0
Cherry	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.0	6.0
Chalky mf	ND	ND	ND	ND	ND	ND	3.0	2.5	ND	ND	ND	ND

ND – not detected; Sour2, bitter2, astringent2 – sour, bitter, and astringent sensations recorded in the end of tasting.*Grape includes berry aromatics; mf – mouthfeel.

In Thailand sample B1 was evaluated as the best juice in all liking attributes (Table 3). The second best sample was E. These samples were both high in sweet and overall sweet attributes, sample E also in candy-like and cherry flavors. Samples D and A were least liked in all respects. Most Thai consumers found the flavor, aftertaste and sour taste intensities of samples D and A too high and sweet taste intensities too low (Table 4). Pomegranate flavor liking was evaluated as unpleasant for all samples but B. While five Estonian, fourteen US and no Spanish consumers reported not being familiar with pomegranate flavor, 29 Thai consumers reported they did not know how pomegranate juice is supposed to taste like. It may be that no expectations exist for the exact pomegranate flavor and familiar flavors are liked better. Thirty-seven consumers altogether said certain samples did not taste like pomegranate juice (A=16, B=2, C=4, D=10, E=5).

3.2.2 Flavor liking between countries

The flavor of sample A (dark-fruity, sour, and astringent) was disliked similarly in Estonia and the US (no significant differences p=0.05, mean scores <5) and disliked even more in Thailand and Spain (Table 3).

Sample B was liked best in Thailand, Estonia and US for overall liking, flavor liking , sweet taste liking, sour taste liking, and pomegranate flavor liking (mean score >5); this was the only sample that had mean scores >6 for some liking attributes. However, sample B was not liked in Spain (mean score <5). Sample B was highest in fruity and vegetable-like notes and was moderately sweet. Differences in liking fro certain characteristics among countries also was reported for green tea (Lee et al., 2010), where US consumers liked samples that were brown, sweet and fruity, while Thai consumers liked fruity samples most.

Sample C, the Spanish sample with chalky mouthfeel and higher musty/earthy falvor notes, was liked best in Spain, a country that grows and processes different varieties of pomegranates than the U.S. or Thailand. Thus, sample C may have a more familiar flavor profile to the Spanish consumers than the other samples we tested. A similar conclusion was noted by Furnols et al., (2011), who found that local foods were preferred by consumers in a study of local and foreign lamb meats. In the study of green tea, Lee et al., (2010) noted that the green teas liked most by US consumers had brown flavor notes often associated with black tea that is more frequently consumed in the U.S. Interestingly, Estonia, the other European country in this study liked sample C as much as Spanish consumers did. Again, familiarity could be the issue, although Estonian conumers liked sample B even more than C. For sweet and sour taste liking Estonian, Spanish, and Thai consumers were opinionated alike, finding juice C slightly pleasant (average score >5). Sample C was disliked in US (mean scores <5).

Consumers, regardless of country, seem to have certain expectations when it comes to pomegranate juice flavor, as was shown with sample D, which was not liked in any country (average scores <5). This may have been caused by the fermented, metallic and high astringent properties which often are negative attributes regardless of country.

Table 3. Mean scores and ANOVA for overall, flavor, sweet taste, sour taste, fruity, pomegranate, and aftertaste liking for Estonia, Spain, Thailand, and US.

Country		Estonia			Spain			Thailand			US		
Sample	Attribute	Mean	bc	wc	Mean	bc	wc	Mean	bc	wc	Mean	bc	wc
A	Overall	4.6	a	c	3.6	b	c	4.0	b	c	4.9	a	b
	Flavor	4.8	a	c	3.4	c	c	4.1	b	c	4.9	a	b
	Sweet	5.1	a	b	3.5	b	c	4.7	a	c	5.0	a	bc
	Sour	5.0	a	b	3.8	c	c	4.5	b	c	4.9	ab	b
	Fruity	5.1	a	bc	3.6	c	c	4.3	b	c	4.9	a	b
	Pom	4.9	a	bc	3.3	c	d	4.3	b	cd	5.1	a	b
	Aftert	4.7	a	b	3.6	c	c	4.1	b	cd	4.7	a	bc
B/B1	Overall	6.1	b	a	4.4	c	b	6.6	a	a	5.8	b	a
	Flavor	6.1	b	a	4.5	c	b	6.7	a	a	5.7	b	a
	Sweet	6.1	a	a	4.2	c	b	6.5	a	a	5.5	b	a
	Sour	5.7	b	a	4.4	c	b	6.3	a	a	5.5	b	a
	Fruity	6.0	b	a	4.7	c	b	6.6	a	a	5.8	b	a
	Pom	6.3	a	a	4.5	b	b	6.0	a	a	6.0	a	a
	Aftert	5.6	a	a	4.3	c	b	5.8	a	a	5.0	b	b
C	Overall	5.3	a	b	5.1	a	a	4.1	b	c	4.0	b	c
	Flavor	5.4	a	b	5.3	a	a	4.7	b	b	4.0	c	c
	Sweet	5.5	a	b	5.7	a	a	5.5	a	b	4.7	b	c
	Sour	5.4	a	ab	5.3	a	a	5.0	a	b	4.3	b	c
	Fruity	5.4	ab	b	5.6	a	a	4.8	bc	b	4.4	c	bc
	Pom	5.0	ab	b	5.5	a	a	4.8	b	b	4.6	b	cd
	Aftert	5.2	a	b	5.2	a	a	4.5	b	bc	4.4	b	c
D	Overall	4.1	a	d	2.9	c	d	3.4	bc	d	3.6	ab	c
	Flavor	4.1	a	d	2.9	c	c	3.8	ab	c	3.5	b	c
	Sweet	4.6	a	c	3.0	c	c	3.8	b	d	3.9	b	d
	Sour	4.1	a	c	3.0	c	d	3.4	bc	d	3.7	ab	d
	Fruity	4.8	a	c	3.2	c	c	4.0	b	c	4.3	ab	c
	Pom	4.6	a	c	2.8	c	d	3.9	b	d	4.3	ab	d
	Aftert	4.1	a	c	3.1	c	c	3.7	ab	d	3.5	bc	d
E	Overall	5.6	a	b	5.4	a	a	5.4	a	b	5.7	a	a
	Flavor	5.6	a	ab	5.7	a	a	5.0	b	b	5.7	a	a
	Sweet	5.5	a	b	5.7	a	a	5.3	a	b	5.4	a	ab
	Sour	5.7	a	a	5.3	ab	a	5.4	ab	b	5.2	b	ab
	Fruity	5.5	ab	b	4.9	b	b	5.3	ab	b	5.7	a	a
	Pom	4.7	a	bc	3.9	b	c	4.9	a	b	4.9	a	bc
	Aftert	5.6	a	a	5.2	ab	a	4.7	b	b	5.5	a	a

Pom – pomegranate; N/A – not available; ES – Estonia, SP- Spain, TH – Thailand, US – U.S; Sample B1 was tested in Thailand and B in all other countries; bc – differences between countries; if letters are different within row, the differences are statistically significant ($p<0.05$); wc – differences within country between juices; if letters are different within column for the same liking, the differences are statistically significant ($p<0.05$); aftert – aftertaste.

Table 4. Intensity % for samples tested. JAR scores with too low and too high % add to 100 unless indicated otherwise.

Intensity	A		B		C		D		E	
Estonia	Too low	Too high	Too low	Too high	Too low	Too high	Too low	Too high	Too low	Too high
Flavor	16.7	67.6	3.9	71.6	42.1	22.5	7.8	84.3	32.3	36.2
Sweet	50.0	19.6	24.5	26.4	14.7	51.9	64.7	10.8	2.9	73.5
Sour	3.9	72.5	8.8	56.8	60.8	2.9	6.8	83.3	47.0	14.7
Fruity	49.0	35.3	19.6	45.1	43.1	25.5	41.1	40.2	45.1	25.5
Pom	47.0*	29.4*	15.7**	49.0**	58.8*	6.8*	37.2***	41.1***	75.5****	3.9****
Aftert	19.6	55.8	4.9	59.8	35.3	18.6	7.8	77.4	27.4	29.4
Spain										
Flavor	21.0	72.0	5.0	78.0	31.0	32.0	15.0	82.0	32.0	37.0
Sweet	72.0	13.0	55.0	18.0	32.0	36.0	75.0	19.0	12.0	58.0
Sour	12.0	77.0	11.0	72.0	49.0	16.0	9.0	88.0	53.0	14.0
Fruity	55.0	36.0	31.0	48.0	30.0	34.0	58.0	32.0	49.0	20.0
Pom	69.0	22.0	45.0	31.0	32.0	32.0	76.0	18.0	82.0	5.0
Aftert	30.0	57.0	15.0	55.0	27.0	36.0	26.0	64.0	38.0	21.0
US										
Flavor	12.8	67.3	3.9	72.2	35.6	41.5	4.9	88.1	25.7	35.6
Sweet	55.4	21.7	45.5	22.7	25.7	38.6	70.3	12.8	7.9	64.3
Sour	6.9	73.2	3.9	59.4	58.4	14.8	1.0	89.1	56.4	6.9
Fruity	45.5	39.6	24.7	42.5	55.4	26.7	45.5	40.6	33.6	35.6
Pom	27.7*	38.6*	15.8*	39.6*	45.5**	20.8**	31.6***	41.5***	51.5****	9.9****
Aftert	6.9	54.4	3.9	52.4	15.8"	39.6"	4.9	78.2	16.8*****	28.7*****
Thailand										
Flavor	9.1	78.1	20.9	20.0	11.8	56.3	10.0	73.6	11.8	58.1
Sweet	61.8	13.6	28.1	14.5	19.1	34.5	79.1	6.3	48.1	18.1
Sour	7.2	75.4	10.9	30.9	65.4	8.1	15.4	80.9	23.6	47.2
Fruity	13.6	69.1	21.8	14.5	17.2	49.1	20.0	66.3	13.6	53.6
Pom	10.0*	20.9*	23.6**	8.1**	7.2***	22.7***	10.9****	27.2****	9.1*****	20.0*****
Aftert	4.5	76.3	10.9	25.4	13.6	52.7	3.6	85.4	10.0	57.2

Estonia: *95% responses; **97% responses; ***96% responses; ****93% responses

US: * 92% responses; **82% responses; ***87% responses; ****83% responses; ***** 98% responses

Thailand: *35.45% responses; ***47.27% responses; *****37.27% responses; **60% responses; ****41.82% responses

There were no significant differences between countries in overall liking and sweet taste liking for sample E. The descriptive data showed this sample to be candy-like and sweet as opposed to natural flavors of other samples. While sample E was liked for overall, flavor, sour, and sweet taste attributes in all of the countries, it was not found very pomegranate-like as pomegranate flavor of sample E was disliked in all countries. The importance of pleasant flavor properties has been discussed in previous literature by Sabbe et al., (2009), and Rabino et al., (2007). Our results indicate pleasant flavor, but also familiar flavor were most important for consumers, although all of the juices presented were pomegranate juices and thus may have healthy properties.

3.2.3 Consumer Clusters

According to clustering results only one juice (D) caused negative liking scores for all consumer clusters (Table 5). Although mean scores showed some disliking in Estonia and US for sample A, it was actually liked by a cluster of consumers in those countries; the same applied for sample B in Spain and sample C in Thailand. Although the mean score of sample C showed liking in Estonia and Spain, and sample E in Estonia, Thailand, and US, there was also a cluster of consumers in those countries who disliked these juices.

Table 5. Mean values and ANOVA for flavor liking clusters in Estonia, Spain, Thailand, and US.

Country	Estonia				Spain				Thailand				US			
Sample	C1 (59)		C2 (41)		C1 (54)		C2 (46)		C1 (52)		C2 (58)		C1 (69)		C2 (32)	
A	5.0	a	4.7	a	3.8	a	2.8	b	4.8	a	3.4	b	5.1	a	4.5	a
B/B1	5.7	b	6.8	a	5.1	a	3.8	b	7.2	a	6.2	b	5.4	b	6.3	a
C	5.8	a	4.8	b	7.1	a	3.2	b	6.5	a	3.1	b	4.0	a	4.0	a
D	4.1	a	4.0	a	3.0	a	2.8	a	4.1	a	3.5	a	3.5	a	3.5	a
E	7.0	a	3.7	b	5.8	a	5.6	a	4.8	a	5.1	a	7.0	a	2.9	b

C1 – cluster 1, C2 – cluster 2, ES – Estonia, SP- Spain, TH – Thailand, US – U.S; If letters are different within country for a sample, the differences are statistically significant ($p<0.05$); The number in the brackets show number of consumers in each cluster.

One of the Thai consumer clusters liked samples C and B with musty and berry flavors and the other cluster liked samples B and E with cranberry, fruity, and candy-like flavors high in sweet aromatics. The two Spanish clusters both liked sample E; however, only one of the clusters liked two additional juices (B and C), while the other cluster found all other juices unpleasant. The flavor liking of Estonian and US consumer clusters were very similar with the exception of one juice. Sample C was liked by one cluster in Estonia, although it was not liked by either of the clusters in the US. Clustering results combined with descriptive data showed toothetch, fermented, sour, bitter, astringent, or metallic flavors were not liked in any country (Fig. 1).

3.2.4 Consumer attitudes

A CATA question was used to determine consumer attitudes towards the different juices. Results were somewhat similar in all countries. The most used clauses by consumers were related to product liking (pleasant flavor, nasty flavor), purchase intent (cheap, I have no interest in bying this, I would consider buying this), juice authenticity (natural color, natural taste, artificial color, artificial taste, fruit juice with other added ingredients, fruit flavored drink), healthy properties (healthy, high in sugar, low in sugar), consumer segments (for adults, for kids, for the entire family), and also some flavor properties (mouthpuckering/astringent, nasty flavor). In Estonia and Thailand it was also relevant whether the flavor was familiar (consumers checked "familiar flavor" or "unfamiliar flavor") or not, indicating attitudes toward new foods may be important. Similar results were reported by Sabbe et al., (2009) in a study with acai juices in Belgium.

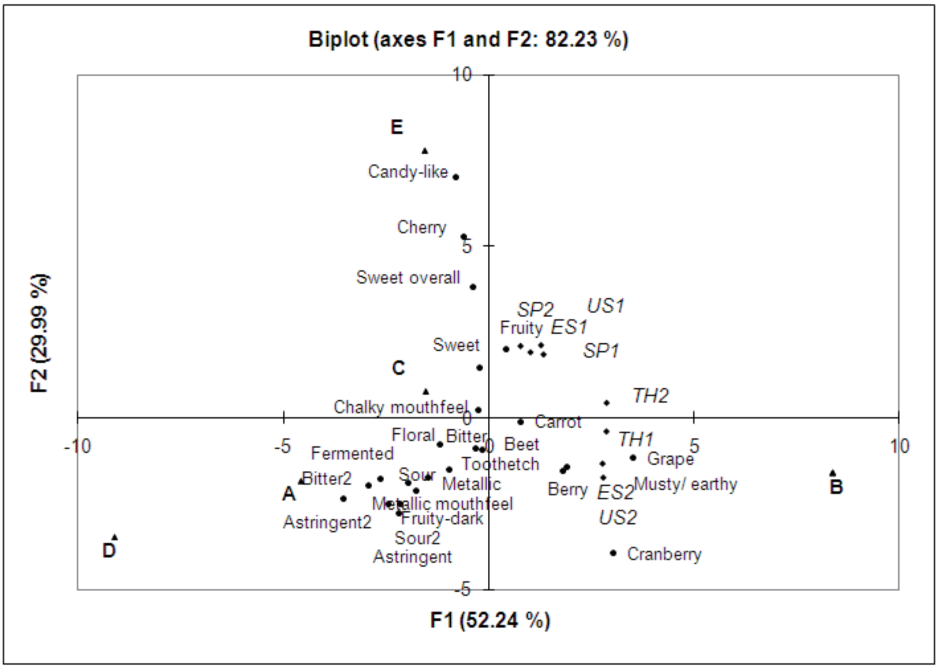

Fig. 1. Consumer clusters flavor liking PCA, descriptive data used as supplementary data. US1, US2 – US clusters 1 and 2; TH1, TH2 – Thailand clusters 1 and 2, ES1, ES2 – Estonian clusters 1 and 2; SP1, SP2 – Spanish clusters 1 and 2.

Spanish consumers found the Spanish juice (sample C) had natural color (n= 43) and natural taste (n=34, Fig. 2). They also found this juice is "for adults" (n=36) "for the entire family" (n=30) and "would consider bying this" (n=30). However, 42 Spanish consumers indicated also that they "have no interest in buying this". This supports the two consumer clusters with split likings toward the Spanish juice. Sample E was found to be "for kids" (n=68), "cheap" (n=36), "high in sugar" (n=42), "fruit juice with other added ingredients" (n=34), and "artificial taste" (n=46). Thirty-two Spanish consumers said they would buy the sample E while 38 thought the opposite. Samples A and D were indicated as having a "nasty flavor" (A=31, D=30), "no interest in buying" (A=75 and D=81), and "astringent" (A=40 and D=74); only one consumer would buy juice D and six would buy juice A. Sample B was considered "for adults" (n=43), "low in sugar" (n=26), and also "mouthpuckering/astringent" (n=62). Although this juice was scored reasonably well in liking, only 23 consumers checked "I would consider buying this" and 52 had no interest in purchasing this juice; which was supported by consumer cluster flavor liking scores.

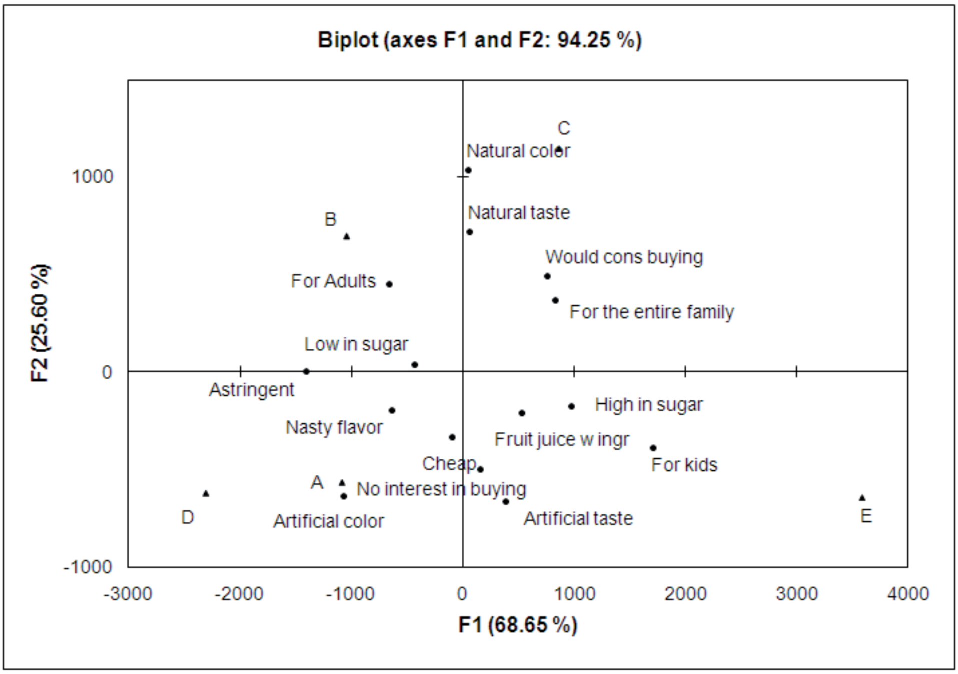

Fig. 2. PCA of top 15 most checked consumer attitude clauses in Spain.

Thai consumers (Fig. 3) checked sample C as having "natural taste" (n=33), "natural color" (n=41), and also as "healthy" (n=29). Samples C, A, and D were considered as "mouthpuckering/astringent" (C=55, A=67, and D=86), "nasty flavor" (C=33, A=38, and D=42), and "unfamiliar flavor" (C=30, A=35, and D=33). Samples B and E were checked as "I would consider buying this" (B=53 and E=17) and "I would drink occasionally" (B=24 and E=27). Samples A and D resembled "fermented flavor" (A=46 and D=39), which to some seemed also as "wine-like flavor" (A=29 and D=27). Descriptive data support those findings (fermented flavor of sample D, sourness and astringency of sample A and D), indicating that consumers and trained panelists were responding similarly to the samples.

Estonian consumers checked samples B and C as "pulpy" (B=27 and C=63), "pleasant flavor" (B=41 and C=23), "natural color" (B=48 and C=28), and "natural taste" (B=41 and C=24, Fig. 4). Sample E was considered having an "artificial taste" (n=56), "high in sugar" (n=65) and being a "fruit flavored drink" (n=45). Samples A and D were both checked as "unfamiliar flavor" (A=38 and D=32), "mouthpuckering/astringent" (A=40 and D=65), "I have no interest in buying this" (A=55 and D=60), and "low in sugar" (A=30 and D=47).

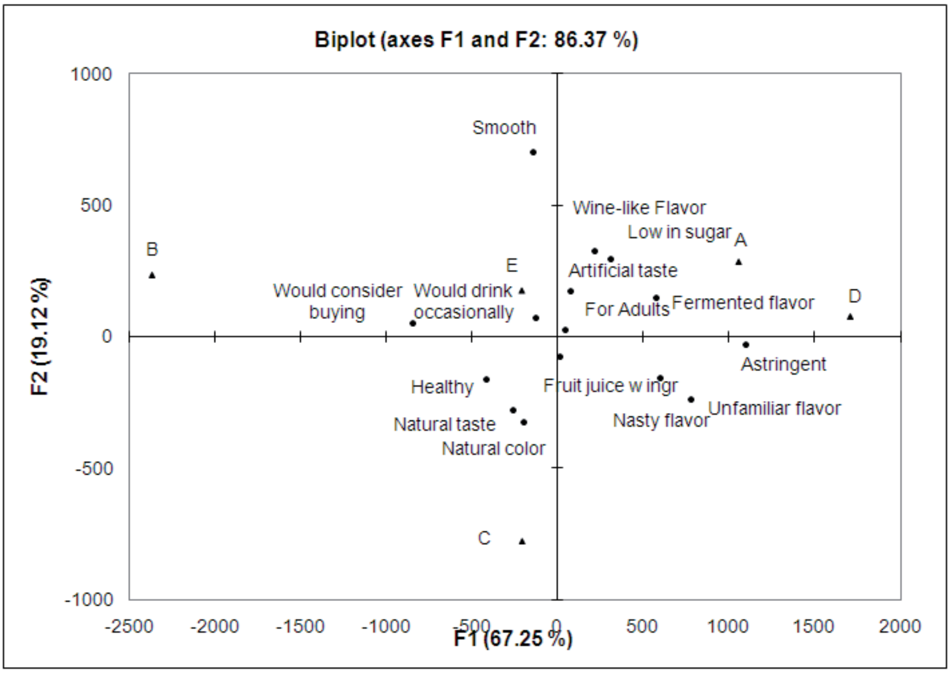

Fig. 3. PCA of top 15 most checked consumer attitude clauses in Thailand.

The only consumers not considering sample C as having a natural taste and natural color were from the US (Fig. 5). According to them, samples C and E were "high in sugar" (C=37 and E=71), "fruit juice with other added ingredients" (C=38 and E=50), "fruit flavored drink" (C=25 and E=37), and had an "artificial taste" (C=32 and E=41). Sample C together with sample D were checked as "nasty flavor" (C=39 and D=39), "fermented flavor" (C=15 and D=41), and "I have no interest in buying this" (C=67 and D=68). Samples A and B were considered to be "healthy" (A=30 and B=49), "for adults" (A=47 and B=49), "mouthpuckering/astringent" (A=44 and B=37) and 31 and 39 consumers respectively checked "I would drink occasionally". The US consumers were open to characterize and name flavors present in juices more than consumers from other countries. For example samples A, B, and D were "fruity like cranberry" (A=34, B=55, and D=32), and samples B, C, and E were "fruity like berry" (B=24, C=21, and E=27).

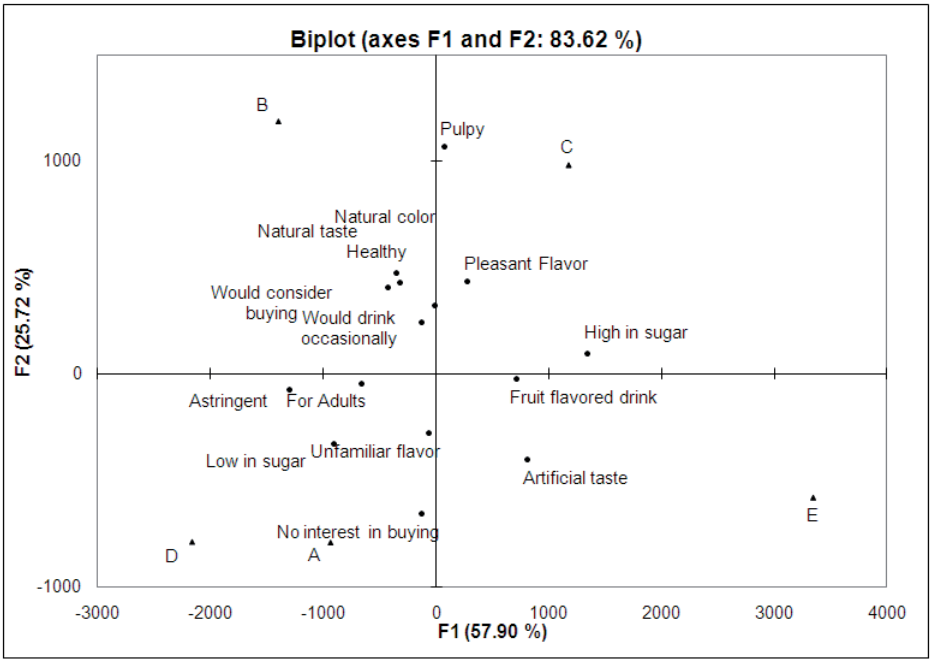

Fig. 4. PCA of top 15 most checked consumer attitude clauses in Estonia.

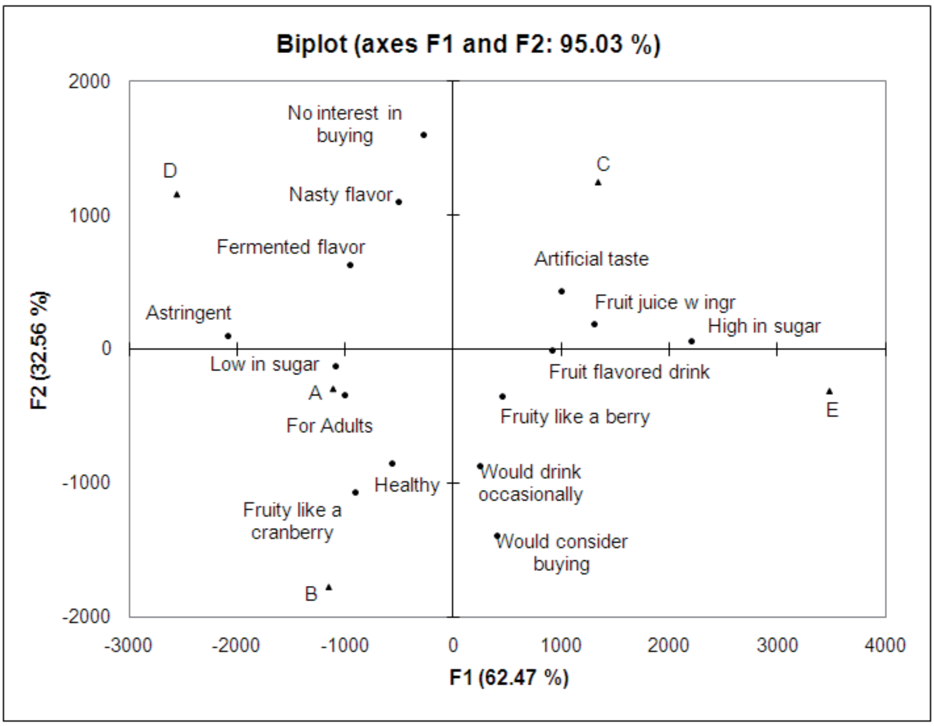

Fig. 5. PCA of top 15 most checked consumer attitude clauses in US.

4. Conclusions

Five pomegranate juice samples, different in their flavor characteristics, were evaluated by consumer panels in Estonia, Spain, Thailand, and US. In Estonia, the US, and Thailand sample B representing juices with high intensities of cranberry and grape, fruity, or berry notes, was liked best, and was followed by the sample which represented sweet and candy-like juices (E). In Spain, the sample representing products characterized by musty/earthy and beet notes (C) and sample E were liked most. Although the best liked sample was different in Spain, similarities were found among all the countries. Sample (E) was well-liked in all of the countries, but was checked as having "artificial taste" or "fruit flavored drink" according to the check-all-that-apply question by some consumers. Sample C was considered natural in taste and color in all countries except for the US. The CATA question also revealed that the most important clauses were related to purchase intent, health issues, product liking, and juice authenticity.

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KOKKUVÕTE

Toidukategooriate väärindamine, kasutades sensoorseid meetodeid

Kategooriate väärindamine on tööstusele suunatud teaduslik meetod, milles kasutatakse konkureerivas võtmes pigem tegelikke produkte kui mudelsüsteeme st hinnatakse toodete potentsiaali. Tootekategooriast parema arusaamise saavutamiseks viiakse tavaliselt läbi toodete kirjeldav sensoorne analüüs ning tarbijauuringud. Antud töös uuriti granaatõunamahlade, juustude, ning maasikamooside kategooriaid.

Töö eesmärgiks oli teha kindlaks maitseprofiilid, mis võivad osutuda edukateks või mis kannavad kohalikku eripära. Seda saavutati läbi järgmiste uuringute: 1) arendati ning rakendati sensoorne sõnavara granaatõunamahlade kategooriale; 2) võrreldi juustude ja maasikamooside maitseid ühel maal ning erinevates maades; 3) võrreldi juustude ja granaatõunamahlade meeldivust ühel maal või erinevates maades. Antud töö uudsus seisneb originaalses uurimustöös, tulemustes, ning publikatsioonides. Antud tööst tulenevad publikatsioonid kirjeldavad Eesti toitu ja maitseid ning ka võrdlevad Eesti toitu mujal maades toodetava ning tarbitava toiduga.

Töö tulemusena valmis granaatõunamahlade kirjeldamiseks sõnavara, mida kasutati edasistes uuringutes värske ning tööstusliku mahla võrdlemiseks ning samuti erinevatest maadest pärit tööstuslike mahlade maitseomaduste võrdlemiseks. Selgus, et granaatõunamahlade maitseomadused tulenevad pigem töötlemistehnoloogiast kui tooraine erinevast asukohamaast. Granaatõunamahlade maitseomaduste järgi võib mahlad grupeerida viide klastrisse; Eestis, Hispaanias, Taimaal, ning USA-s tarbijatega läbiviidud meeldivusuuringu kohaselt võivad teatud omadustega mahlad, nagu näiteks magusa-, hapu-, jõhvika-, viinamarja-, ja marjamaitselised mahlad olla edukad enamikus uuritud riikides.

Maasikamooside tootekategoorias ei leitud tootmismaa mõju toodete sensoorsetele omadustele. Maasikamoosid jagunesid kolme klastrisse, mida iseloomustati nii sensoorsete kui instrumentaalsete mõõtmiste abil; nendest üks klaster, mida iseloomustati punase värvuse, magusa maitse, ning rohke marjasisaldusega, võib olla edukas tarbijate hulgas.

Eesti juustud on piimale iseloomulike, kohati magusa aroomi või võihappele omase aroomiga ning varieeruvad teravate ning aegunud juustudele omaste maitseomaduste poolest. Ühele osale Eesti tarbijatest meeldivad nooremad juustud, mis on piimasema maitsega ning teisele osale vanemad juustud, mis on tugevama ning teravama maitsekooslusega. Kui Eesti juuste võrrelda Euroopa juustudega, siis ilmneb, et Eesti juustude maitse ei varieeru suurel määral. Teistes Euroopa maades leidub mitmeid juuste, mis on Eesti juustudega sarnased, mistõttu võivad Eesti juustud osutuda edukateks ka mujal.

Kokkuvõtteks võib öelda, et kategooria väärindamine läbi kirjeldava sensoorse analüüsi ning tarbijauuringute osutus sobilikuks lähenemiseks toote potentsiaali hindamisel. Toodete klasterdamine maitseomaduste järgi ning tarbijate klasterdamine meeldivuse järgi annab toiduaineteadlastele ning tööstusele kasulikku lisainformatsiooni.

APPENDIX 1 CURRICULUM VITAE

Curriculum Vitae

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