The characterization of the most-liked reduced-fat Havarti-type cheeses

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ABSTRACT

In Finland, official recommendations state that reduced-fat cheese should be used in the everyday diet. Finnish consumers are increasingly willing to consume food with a reduced fat content, and sales of reduced-fat cheeses have been increasing. The consumers who participated in this study ($n = 153$; 17 to 78 yr old) ate reduced-fat cheeses on a weekly basis. They were recruited from supermarket customers living in a metropolitan area in Finland. The object of this study was to determine which kind of reduced-fat Havarti-type cheeses were most liked. The study consisted of a consumer test, sensory descriptive analysis, and chemical analysis of commercial reduced-fat Havarti-type cheeses ($n = 10$). The results of the sensory quantitative descriptive analysis were compared with consumer hedonic ratings by external preference mapping. In addition, information on composition (fat, salt, and free amino acids) was gathered and compared with the hedonic ratings. The preferred sensory properties were a pale appearance, sticky texture, and rich flavor. However, the consumers could be grouped according to their preferences on appearance and consistency. The main attributes contributing to the grouping of consumers were stickiness, hardness, and yellow color. The least preferred cheeses among all Finnish consumers were those with the lowest flavor intensities. The consumers preferred the cheeses with the highest salt content.

Key words: preference mapping, quantitative descriptive analysis, reduced-fat cheese

INTRODUCTION

Consumers' willingness to purchase food with a reduced fat content has been increasing in Finland during recent years. In 2004, almost half of all cheese consumed in Finland was reduced-fat cheese. A meta-analysis by Astrup et al. (2000) advocated a low-fat diet as a way

to control BW. Furthermore, a recent review (Scholz-Ahrens and Schrezenmeir, 2006) claimed that reduced-fat dairy products positively affect metabolic health as they can help with weight reduction. In addition to their reduced energy content, the calcium content of dairy products may prevent metabolic syndrome. However, other diets might be as beneficial to metabolic health as a low-fat diet. Some studies have indicated that a low-carbohydrate diet could be as good as or better than a low-fat diet in decreasing the risk of the metabolic syndrome (Meckling et al., 2004). Nonetheless, it is an official recommendation that reduced-fat cheese should be used in everyday life. The American Dietetic Association and the Dietitians of Canada also recommend low-fat dairy products (Kris-Etherton et al., 2007).

Reduced-fat cheeses have been characterized as bitter (e.g., Madsen and Ardö, 2001; Mistry, 2001), chewy (Gwartney et al., 2002), firm (Fenelon and Guinee, 2000), or considered to be of "low quality" (Jack et al., 1994). With time, however, many technological advances have been introduced to improve the sensory quality of low-fat cheeses (Mistry, 2001; Banks, 2004).

Havarti-type cheeses are the most popular cheese varieties in Finland, along with Edam and Emmental cheeses (AC Nielsen ScanTrack, 2001; www.nielsen.com). The typical fat content of Havarti-type cheeses is 45 to 55% of DM, with a minimum DM content of 50% (by weight) (Codex Standard for Havarti, 267–1966). Havarti-type cheeses are interior-ripened cheeses with a mild, creamy flavor and a fresh acidic taste. This semi-hard cheese resembles Tilsit and was made in earlier times on a farm in Havarti, in North Zealand, Denmark. It is normally made from cow milk but there are no limitations on the breed of cow. In northern Europe, the milk is typically pasteurized. Originally, the whey was drained off before cheese pressing. Today, manufacturing processes can vary to some extent. Rennet is used and the curd is pressed and drained in molds. The Havarti-type cheese is a cooked cheese in which the fat content, size, and shape may vary. The cheese may be wrapped in a film or allowed to form a rind, which may be rather dry with a tendency to greasiness. The color

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of the rind is typically yellow-red to brown and the body is light yellow with numerous small, irregularly shaped holes. Havarti-type cheese is softer than other semihard varieties and has a fuller flavor. The cheeses are matured for 4 wk to 6 mo. (Davis, 1976).

In addition to fat, salt and free amino acids (FAA) are known to affect cheese flavor significantly. The FAA are produced during maturing due to proteolysis. Some FAA are known to be bitter-tasting compounds. The salt content in reduced-fat cheeses might be increased to enhance flavor (Saint-Eve et al., 2009) and decrease bitterness in cheeses (Mistry and Kasperson, 1998). Furthermore, salt content is an important factor in texture. However, salt is a well-known contributor to hypertension (Karppanen and Mervaala, 2006). The limit for heavy salting in cheeses is 1.3% by weight (Decision of the Ministry of Trade and Industry on Labeling of Foodstuffs 2.12.2004/1084; Anon., 2007) in Finland. As cheese consumption has increased, the significance of salt intake from cheeses has increased accordingly.

Cheeses with at least a 30% reduction in fat content are called reduced-fat cheeses (Regulation EC No. 1924/2006 on nutrition and health claims made on foods). In a previous study (Ritvanen et al., 2005), we found that the common reduced-fat cheeses on the Finnish market are considered by consumers to be just as pleasant as regular fat cheeses. Levis et al. (2000) also have demonstrated that reduced-fat cream cheeses with 40% less fat can be preferred as much as their full-fat counterparts. However, some differences between attributes concerning pleasantness of regular-fat and reduced-fat Havarti-type cheeses were reported. "Aftertaste" and "flavor intensity" were more important to the pleasantness of reduced-fat cheeses than that of regular-fat cheeses, which might indicate different reasons behind a preference for a particular reduced-fat Havarti-type cheese. In addition, the variation in mean hedonic scores for reduced-fat cheeses was greater than for regular-fat Havarti-type cheeses.

The objective of this study was to discover which types of reduced-fat Havarti-type cheeses are most liked when the comparison is limited exclusively to reduced-fat cheeses. In contrast to Childs and Drake (2009), we assumed that regular consumers of reduced-fat cheeses do not expect the cheese to resemble a full-fat cheese. It has been demonstrated that eating cheeses with a modified fat content may affect preference (Levis et al., 2000). For the study, reduced-fat cheeses were considered a distinct dairy product. Thus, by limiting the samples to reduced-fat cheeses, it was possible to highlight the differences among these cheeses, rather than focusing on the differences between reduced-fat cheeses and their full-fat counterparts. In addition, the negative attitude toward low-fat dairy products could be

Table 1. The dairies producing the commercial cheeses examined in this study

Dairy	Location	Samples, n
Arla Foods co-operative dairy	Viby, Denmark	1
Ilmajoki co-operative dairy	Ilmajoki, Finland	1
Ingman Ltd.	Söderkulla, Finland	1
Juustoportti Ltd.	Jalasjärvi, Finland	1
Milka co-operative dairy	Kaitsor, Finland	2
NorrOst dairy	Malmö, Sweden	1
Skåne mejerier dairy	Malmö, Sweden	1
Valio Ltd.	Helsinki, Finland	2

negated because full-fat cheeses were excluded from the comparison (Kähkönen and Tuorila, 1999; Yackinous et al., 1999). The results of the sensory quantitative descriptive analysis (QDA; Stone and Sidel, 1993) were compared with hedonic ratings by external preference mapping. Preference mapping is a group of techniques applied to relate sensory attributes and consumer liking and to characterize market segmentation (McEwan, 1996; Helgesen et al., 1997). It has been widely used for full-fat cheeses (Young et al., 2004; Hersleth et al., 2005; Caspia et al., 2006). In addition, the fat, salt, and FAA contents the cheeses were correlated with the hedonic ratings and QDA.

MATERIALS AND METHODS

Samples

The samples were 10 commercial Havarti-type cheeses with reduced fat contents. The cheeses with the highest market volumes were chosen. The samples were produced in 8 dairies (Table 1). The subsamples for different analyses were always from the same batch. The total amount of a cheese was approximately 16 kg.

Sensory Profile

The sensory profile test was carried out by the QDA (Stone and Sidel, 1993). The assessors ($n = 9$) were experts who have been involved in the sensory analysis of cheeses for more than 5 years. Three separate training sessions (lasting 4 h each) with various cheeses and reference samples were organized. In addition, reference materials were available for the assessors for independent training between training sessions. The jury in a previous study (Ritvanen et al., 2005) used this same profiling method; thus, a revision of the method was considered adequate. The sufficiency of training was evaluated by examining deviations of the jury from the mean values.

The sensory attributes concerned appearance, texture, and flavor (Table 2). A linear scale (10 cm, ver-

Table 2. The sensory attributes in the quantitative descriptive analysis

Attribute	Abbreviation	Definition
Yellowness	Yell	Intensity of color of cheese mass
Evenness of color	ColEven	Evenness of color in cutting surface; evenness means not speckled, mottled, streaky, or marbled
Deviation of holes	HDev	Evenness of hole deviation on the surface
Amount of holes	HAm	Average number of holes in the cutting surface
Size of holes	HSi	Size of holes
Hardness	Hard	Softness/hardness of cheese mass as determined by fingers
Elasticity	Elas	Drag felt while bending a piece of cheese; elastic cheese is difficult to break
Toughness	Tough	Difficulty of chewing as determined when a piece is ready to be swallowed
Crystallinity	Cryst	A characteristic of aged cheese; crystals grate in the mouth
Stickiness	Sticky	Sticky cheese sticks to teeth and mouth surfaces
Flavor intensity	FlavInt	Intensity of all flavors as sensed when tasting the cheese for the first time
Saltiness	Salty	Salty taste sensation elicited by salts
Sourness	Sour	Sour taste sensation elicited by acids
Rich flavor	Flav_rich	Greasy mouthfeel in balance with flavor
Balance of flavors	Flav_bal	Balance of flavor means that no one flavor overwhelms the other flavors
Bitterness	Bitter	Bitter taste sensation as elicited by caffeine or free AA
Aftertaste	AfterT	Intensity of taste determined 30 s to 1 min after swallowing (or spitting)

bally anchored at both ends; e.g., weak, strong) was used. One attribute (size of the holes) was additionally anchored in the middle. All 10 cheeses were presented to assessors in 1 session, and no time limit for evaluation was set. The samples were coded with 3-digit numbers and presented to the assessors in a randomized order. The attributes concerning appearance were evaluated by test samples with the same size as in the consumer packages (approximately 5 cm × 7 cm × 12 cm), and the attributes concerning flavor were evaluated by test samples sized approximately 4 cm × 5 cm × 2 cm. The texture was evaluated by both test sample sizes. Sample temperature was 14 ± 2°C. The sensory profile test was carried out in duplicate.

Consumer Test

A product test for liking was arranged. Consumer preference for appearance, mouth feel, flavor, and overall liking were evaluated with the 9-point classical hedonic scale (Peryam and Pilgrim, 1957). Points 6 to 9 meant that the subject liked the sample, points 1 to 4 represented disliking the sample, and point 5 was taken as neither liking nor disliking the sample.

The attitude of the consumer toward low-fat food can influence preference (Solheim and Lawless, 1996), so only regular consumers of reduced-fat cheeses were surveyed. Attitude was evaluated indirectly. When an individual reported regular consumption of reduced-fat cheeses, he or she was estimated to have at least a neutral attitude. Likewise, Levis et al. (2000) suggested that in the case of individuals currently consuming higher fat products, expectations about modified-fat products may be different.

Consumers (n = 153) were clients in 3 supermarkets in a metropolitan area of Finland. The consumers were recruited personally. They were told that samples were

of reduced-fat Havarti-type cheeses. The consumers were mostly women (68%) 17 to 78 (mean 49) yr old, and 57% of the consumers had a secondary education. Consumers tested were regular eaters of reduced-fat cheeses; 86% reported eating these products at least weekly.

The samples (approximately 4 cm × 5 cm × 2 cm) were coded with letters randomly extracted from the middle parts of the alphabet and presented in a randomized order. Paper ballots were used. Consumers were requested to rinse their mouths with water between samples.

Chemical Analysis

A test sample of approximately 500 g was homogenized for chemical analyses. Dry matter, fat, and salt were analyzed in duplicate by International Dairy Federation standard methods (IDF, 1982; IDF, 1986; IDF, 1988; respectively). The above methods are accredited in our laboratory according to EN ISO/IEC 17025. The FAA were analyzed by a titration method (Moisio and Heikonen, 1996).

Statistics

The results of the QDA were analyzed by 2-way ANOVA (factor: cheese, assessor) and principal components analysis. The results of the consumer hedonic tests were assessed by ANOVA (factor: cheese), and statistically significant differences ($P < 0.05$) were tested by Tukey's test. The experimental design in the consumer hedonic tests was a randomized block (block = consumer). Correlations ($P < 0.05$) of the consumer hedonic tests, the chemical analysis, and the QDA results were obtained by Spearman rank correlation test.

Preference mapping was done by principal component regression. The results of the QDA were x-variables, and the hedonic ratings (overall liking) were y-variables. Hierarchical cluster analysis (complete linkage) was carried out to divide the consumers into subgroups according to their preference similarities. The statistical tests were carried out using Statistix for Windows (2.0, Analytical Software, Tallahassee, FL), Unscrambler (9.2, CAMO ASA, Oslo, Norway), and SPSS for Windows (11.5, SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Sensory Profile

The differences between cheeses in all attributes except crystallinity, toughness, and bitterness were statistically significant ($P < 0.05$). The results of the QDA are presented in Table 3.

Bitterness has been linked with reduced-fat cheeses (Mistry, 2001), but in this study, reduced-fat Havarti-type cheeses were rated as having only a moderate bitter taste (bitterness ranged from 3.7 to 5.8). In our earlier study (Ritvanen et al., 2005), similar values for bitterness were observed for all Havarti-type cheeses. Likewise, in Danbo cheeses with different fat contents (Madsen and Ardö, 2001), the level of bitterness was low and no significant differences were found among the cheeses. Other characteristics associated with reduced-fat cheeses in general are that they are chewy (“tough”) and firm (“hard”). The tested cheeses were slightly tough (toughness ranged from 3.1 to 4.8). This is in accordance with an earlier study (Ritvanen et al., 2005), where reduced-fat Havarti-type cheeses were as chewy as their regular-fat counterparts. Nevertheless, the cheeses varied significantly in hardness (1.4 to 7.0; $P < 0.001$). Elasticity ranged from 2.6 to 6.4 ($P < 0.001$).

A full, creamy flavor is characteristic for Havarti-type cheese. “Rich flavor” and “balance of flavors” ranged from 4.0 to 6.2 and from 3.6 to 6.4, respectively ($P < 0.001$ for both attributes). In addition, all cheeses had a moderate sour (4.9 to 6.6; $P < 0.01$) and salty taste (3.0 to 6.5; $P < 0.001$). It can be concluded that the cheeses were sufficiently different from each other to allow us to determine the characteristics preferred by consumers.

Consumer Test

All cheeses performed well in the consumer test for liking. A summary of the results is presented in Table 4 (df = 9, 1,368; pleasantness of appearance: $F = 10.615$, $P < 0.000$; pleasantness of mouth feel: $F =$

Table 3. The sensory analysis of the cheeses by quantitative descriptive analysis

Sample	Attribute ¹																
	Yellow***	ColEven***	HDev***	HAM***	HSI***	Hard***	Elas***	Tough	Cryst	Sticky***	FlavInt***	Salty***	Sour**	FlavRich***	FlavBal***	Bitter	AfterT***
K69	5.2 ^{bcd}	6.6 ^{abc}	8.0 ^a	8.9 ^a	5.3 ^b	1.4 ^d	4.6 ^{bc}	3.1 ^a	2.2 ^a	6.1 ^{ab}	5.4 ^{abcd}	4.6 ^{bcd}	6.4 ^a	4.8 ^{ab}	4.5 ^{bc}	5.4 ^a	5.6 ^{ab}
U54	3.1 ^f	6.4 ^{abc}	3.1 ^c	5.0 ^{cd}	6.9 ^a	2.3 ^{cd}	3.9 ^{bcd}	3.4 ^a	1.8 ^a	6.5 ^a	6.0 ^{abc}	6.5 ^a	6.6 ^a	5.3 ^{ab}	5.4 ^{ab}	4.2 ^a	6.0 ^{ab}
U41	4.3 ^{def}	3.9 ^d	4.8 ^{bc}	4.8 ^d	5.2 ^b	7.0 ^a	2.6 ^d	3.5 ^a	2.4 ^a	3.6 ^{cde}	6.2 ^{ab}	4.5 ^{bcd}	5.6 ^{ab}	6.2 ^a	6.4 ^a	3.7 ^a	5.9 ^{ab}
U71	3.9 ^{ef}	5.7 ^{abcd}	5.7 ^b	6.3 ^{bc}	4.8 ^b	3.3 ^c	4.0 ^{bcd}	3.4 ^a	2.3 ^a	5.6 ^{abc}	5.8 ^{abc}	4.8 ^{bc}	5.8 ^{ab}	5.2 ^{ab}	5.3 ^{ab}	4.5 ^a	5.2 ^{bc}
K74	4.8 ^{cde}	5.3 ^{bcd}	6.2 ^{ab}	6.5 ^b	6.9 ^a	3.5 ^{bc}	5.2 ^{ab}	3.9 ^a	1.9 ^a	4.1 ^{bcd}	5.2 ^{bcd}	4.1 ^{bcd}	5.3 ^{ab}	4.3 ^b	4.2 ^{bc}	5.8 ^a	5.8 ^{ab}
K16	5.0 ^{cde}	7.1 ^{ab}	6.4 ^{ab}	5.7 ^{bcd}	4.3 ^b	3.0 ^c	6.4 ^a	4.2 ^a	2.0 ^a	5.3 ^{abcd}	3.6 ^c	3.0 ^d	4.9 ^b	4.0 ^b	3.6 ^c	4.5 ^a	4.0 ^c
K91	6.9 ^a	4.7 ^{cd}	5.5 ^b	5.9 ^{bcd}	3.0 ^c	6.3 ^a	2.6 ^d	3.5 ^a	2.3 ^a	4.9 ^{abcde}	6.7 ^a	5.4 ^{ab}	6.1 ^{ab}	6.2 ^a	6.4 ^a	4.9 ^a	6.8 ^a
K62	6.5 ^{ab}	7.2 ^a	6.5 ^{ab}	5.7 ^{bcd}	2.2 ^c	6.8 ^a	3.3 ^{cd}	3.9 ^a	1.6 ^a	3.0 ^{de}	6.0 ^{abc}	4.2 ^{bcd}	5.5 ^{ab}	6.2 ^a	6.3 ^a	4.0 ^a	5.9 ^{ab}
K22	5.8 ^{abc}	4.9 ^{cd}	5.8 ^b	6.3 ^{bc}	4.4 ^b	4.6 ^b	5.5 ^{ab}	4.8 ^a	1.7 ^a	2.8 ^e	4.6 ^{cde}	4.7 ^{bcd}	5.6 ^{ab}	4.4 ^b	4.4 ^{bc}	4.1 ^a	4.9 ^{bc}
K38	5.6 ^{abcd}	6.3 ^{abc}	6.2 ^b	6.8 ^b	5.0 ^b	6.0 ^a	4.0 ^{bcd}	3.6 ^a	2.3 ^a	3.7 ^{cde}	4.0 ^{de}	3.2 ^{cd}	5.5 ^{ab}	4.0 ^b	3.9 ^c	4.6 ^a	5.1 ^{bc}

^{a-f}Means within a column with the same letter do not differ significantly ($P < 0.05$).
¹Yellow = yellowness; ColEven = evenness of color; HDev = deviation of holes; HAM = amount of holes; HSI = size of holes; Hard = hardness; Elas = elasticity; Tough = toughness; Cryst = crystallinity; Sticky = stickiness; FlavInt = flavor intensity; Salty = saltiness; Sour = sourness; FlavRich = rich flavor; FlavBal = balance of flavor; Bitter = bitterness; AfterT = aftertaste.
** $P < 0.01$; *** $P < 0.001$.

Table 4. The results of the consumer hedonic test

Sample	Overall liking	Pleasantness of flavor	Pleasantness of mouth feel	Pleasantness of appearance
K69	6.69 ^a	6.56 ^a	6.57 ^a	6.75 ^{ab}
U54	6.61 ^a	6.54 ^a	6.50 ^a	6.60 ^{abc}
U41	6.56 ^{ab}	6.42 ^a	6.37 ^{ab}	6.68 ^{abc}
U71	6.51 ^{ab}	6.26 ^{ab}	6.33 ^{ab}	6.90 ^a
K74	6.48 ^{ab}	6.41 ^{ab}	6.31 ^{ab}	6.95 ^a
K16	6.26 ^{ab}	6.21 ^{ab}	6.25 ^{ab}	6.68 ^{abc}
K91	6.22 ^{ab}	6.07 ^{ab}	6.22 ^{ab}	5.86 ^d
K62	6.21 ^{ab}	6.16 ^{ab}	6.14 ^{abc}	6.24 ^{cd}
K22	6.04 ^{bc}	5.88 ^{bc}	5.88 ^{bc}	6.67 ^{abc}
K38	5.67 ^c	5.53 ^c	5.61 ^c	6.31 ^{bcd}

^{a-d}Means in a column marked with same letter do not differ significantly ($P < 0.05$).

5.266, $P < 0.000$; pleasantness of flavor: $F = 7.031$, $P < 0.000$; overall liking: $F = 7.137$, $P < 0.000$). Eight out of 10 samples comprised group A in Tukey's test. The relatively high liking scores may be explained by the consumers' positive attitude. In addition, Tuorila et al. (1994) suggested that subjects who deliberately use reduced-fat products have positive expectations about all fat-free products. Furthermore, Solheim and Lawless (1996) have found that subjects with a positive attitude toward low-fat food rated reduced-fat Cheddar higher than its regular-fat counterpart. This fact was independent of the awareness of the fat content. In this study, no direct measurement of attitude was assessed. However, because food choice is a free choice, we assumed that consumers of reduced-fat cheeses purchased and ate the cheeses voluntarily.

The narrow range of liking was not unexpected. Hersleth et al. (2005) did not find any significant differences for liking of Norway cheeses, and in another study (Drake et al., 2008), overall liking of mild Cheddar varied from 5.3 to 6.6 on a 9-point hedonic scale. Consumers can be fickle in their preferences, thus mean values of liking scores can be nondiscriminating. Furthermore, Lawlor and Delahunty (2000) have shown that some consumer segments might be missed when only mean values of liking are taken into account.

In this study, one consumer was excluded from the preference mapping because of invariable scoring (the individual always chose the same value for liking). It is possible that more consumers were incapable of evaluating the samples, either because they could not sense any differences or were unable to use the scale. For instance, Lawlor and Delahunty (2000) excluded 18% of consumers, and Childs and Drake (2009) omitted 12% in a Cheddar study and 14% in a Mozzarella study. Liggett et al. (2008) used cluster analysis for the separation of nondistinguishers (40% of respondents). However, in this study, no further selection of consumers was implemented. The preference mapping shows (Figure

1) consumers evenly spread throughout the map, hence selection of consumers was considered unnecessary.

Chemical Analysis

The fat content of the cheeses varied from 15.1 to 20.4%, and the salt content varied from 0.7 to 2.3% (Table 5). The DM content is shown in Table 5 as another way to characterize the samples. The FAA levels varied in the same general range as that reported earlier (i.e., from 80 to 225 mmol/kg; Table 5; Ritvanen et al., 2005). Madsen and Ardö (2001) reported total amounts of FAA ranging from 74 to 85 mmol/kg for 3 Danbo cheese with varying fat content and 7-wk ripening time. The actual ripening times for the cheeses in this study are unknown; however, in general, Havarti-type cheeses are ripened for less than 6 mo.

Cheese is a noticeable source of salt in the diet (Saint-Eve et al., 2009). In an earlier study, the highest salt content in Havarti-type cheeses was 1.6% (Ritvanen et al., 2005), which indicates a possible tendency to increase the salt content in Havarti-type cheeses. The limit for heavy salting in cheeses has been set to 1.3% by weight in Finland. In light of the current legislation, 6 out of 10 samples examined were considered to be "heavy salted." The salt contents were slightly lower than the salt contents of commercial Cheddar cheese, which ranged from 1.3 to 3.3% (wt/wt), in one study (Kilcawley et al., 2007). In that study, the 2 reduced-fat Cheddar cheeses had 1.4% salt.

Correlations to Chemical Analysis

Neither "rich flavor" nor "balance of flavors" correlated with the fat content, as one might have predicted. This is in accordance with the findings of Saint-Eve et al. (2009), who found that butter perception was independent of fat content. Fenelon et al. (2000a) stated that full-fat Cheddar was rated as creamier and more buttery

Figure 1. a) Principal component analysis (scores and loadings) of the samples and the quantitative descriptive analysis (QDA); b) principal component regression loadings of the QDA (x-variable) and the consumer hedonic tests (y-variable); preference mapping. The consumer subgroups are indicated by symbols (dot, star, triangle, and square); Yellow = yellowness; ColEven = evenness of color; Hole_dev = deviation of holes; Hole_amount = amount of holes; Hole_size = size of holes; Hard = hardness; Elastic = elasticity; Sticky = stickiness; Flav_int = flavor intensity; Salty = saltiness; Sour = sourness; Flav_rich = rich flavor; Flav_bal = balance of flavor; AfterT = aftertaste. Color version available in the online PDF.

than reduced-fat cheeses. Furthermore, Kilcawley et al. (2007) stated that full-fat Cheddar was rated as more “balanced.” In our study, all samples were reduced-fat cheeses and therefore similar connections between rich

flavor and fat content could not be made. When fat content is constant, the differences in flavors associated with fat might originate from age. Caspia et al. (2006) found that a 9-mo-ripened cheese had a more cooked,

Table 5. The chemical composition of the cheeses (mean values)¹

Sample	Fat, %	DM, %	Salt, %	Free AA, mmol/kg
K69	15.1	56.1	1.9	120
U54	15.9	50.2	2.3	121
U41	18.5	56.4	1.5	213
U71	16.0	52.4	1.4	163
K74	16.2	51.6	1.0	112
K16	19.3	54.0	1.5	112
K91	18.2	49.8	1.4	225
K62	19.0	56.0	1.3	212
K22	18.1	54.3	0.7	80
K38	20.4	56.1	1.2	108

¹Fat and salt are expressed as a percentage of wet basis.

buttery, and creamy taste than the 7- or 12-mo-ripened cheeses. Furthermore, Fenelon et al. (2000a) proposed that “balanced” flavor reflects more subtle differences between cheeses in concentrations and types of volatile compounds developing during ripening.

Fat content did not correlate with the FAA levels, which is in contrast with the report of Kebary et al. (1999), in which a decrease in fat content caused a decrease in total FAA content. The lower moisture and higher salt contents of low-fat cheeses were postulated to suppress the growth of proteolytic bacteria. Fenelon et al. (2000b) also claimed that an increase in fat content would increase primary proteolysis in Cheddar. Nonetheless, the cheeses in our study were produced in different dairies and many other factors—for example, different manufacturing conditions—had a greater influence on FAA formation than did fat content (Madsen and Ardö, 2001).

Salt content may have a significant influence on saltiness, sourness, and yellow color (Wendin et al., 2000), but no such correlations were found. Salty flavor was independent of salt content ($P > 0.05$). The salty flavor was perhaps masked by other sensory attributes. Salt can also decrease bitterness (Mistry and Kasperson, 1998), but in this study, salt content did not affect bitterness.

The FAA levels were positively correlated with flavor intensity [Spearman correlation coefficient (r_s) = 0.915; $P < 0.05$], flavor richness (r_s = 0.892; $P < 0.05$), balance of flavors (r_s = 0.890; $P < 0.05$), and aftertaste (r_s = 0.787; $P < 0.05$). It can be concluded that FAA formation is an important factor for the flavor of reduced-fat Havarti-type cheeses. Pripp et al. (2006) found a similar correlation between FAA content and flavor intensity for Präst cheese. This also is in accordance with Fenelon et al. (2000a), who stated that total FAA content was independent of the fat content, but that FAA was a factor in discriminating between mild and mature Cheddar. Kilcawley et al. (2007) also reported that fat content had no influence on proteolysis.

Correlations to Consumer Test

The attributes correlating to overall liking are presented in Table 6. In this study of Finnish consumers of reduced-fat cheese, fat content correlated negatively to overall liking ($P < 0.05$, Table 6), even though fat content varied only slightly.

Salt content correlated positively to overall liking ($P < 0.01$, Table 6), pleasantness of mouth feel ($P < 0.05$, data not shown), and pleasantness of flavor ($P < 0.05$, data not shown). Furthermore, the 2 most preferred cheeses were the most salted ones. Saint-Eve et al. (2009) found that a reduced-fat cheese with higher salt content was perceived as being more intense in overall aroma. This might also be the explanation here, although “flavor intensity” did not correlate directly to overall liking. Moreover, it is known that salt influences texture, and Saint-Eve et al. (2009) proposed that salt has a greater effect on products with a reduced fat content.

Eating highly salted cheeses may affect overall salt intake, which in turn is connected to the risk of hypertension. In this study, a preference for highly salted reduced-fat cheeses was observed. From a health standpoint, this is unfortunate because reduced-fat dairy products are recommended as a part of a healthy diet. It is evident that there is a need to devise a tasty low-fat cheese with only moderate salt content.

Pleasantness of mouth feel and flavor were clearly correlated with overall liking ($P < 0.01$); however, the pleasantness of appearance did not correlate to overall liking. It seems that consumers prioritize mouth feel and flavor over appearance. Similarly Young et al. (2004) found strong relationships between “overall acceptance” and “overall flavor liking,” as well as “overall texture liking” of Cheddar. The overall liking correlated positively to the size of holes and stickiness, and negatively to yellow color and toughness ($P < 0.05$, Table

Table 6. The consumer preferences, the quantitative descriptive analysis (QDA) attributes by experts, and the chemical attributes correlated to overall liking

Attribute	r_s ¹
Consumer preference attributes	
Pleasantness of flavor	0.976**
Pleasantness of mouth feel	1.000**
QDA attributes	
Yellowness	-0.685*
Hole size	0.620*
Toughness	-0.734*
Stickiness	0.709*
Chemical attributes	
Fat content	-0.733*
Salt content	0.787**

¹Spearman correlation coefficient.

* $P < 0.05$; ** $P < 0.01$.

6). However, in this study, differences between cheeses in toughness were statistically nonsignificant.

The pleasantness of appearance correlated positively to the size of holes and negatively to yellow color ($P < 0.05$, data not shown). A yellow color is usually associated with the fat content of cheese (Wendin et al., 2000). In this study of Finnish consumers of reduced-fat cheeses, an attribute connected to the fattiness (i.e., yellowness) was not preferred.

Bitterness had a nonsignificant influence on the hedonic scores (data not shown). It can be concluded that although some bitterness might have been detected, this was not displeasing to the Finnish consumer.

Preference Mapping

Preference mapping was used to clarify the relationships between sensory characteristics and consumer preference (McEwan, 1996). One consumer was omitted because she rated all cheeses identically. In addition, the QDA variables with statistically nonsignificant differences between samples (crystallinity, bitterness, and toughness) were omitted. Two principal components (PC1 and PC2) explained 72% of the variation in the data. The results of principal component analysis and principal component regression are summarized in Figures 1a and 1b.

Cheeses K38 and K22 are adjacent in Figure 1a; they were the least-liked cheeses (group C in Tukey's test; Table 4). These particular cheeses were yellow and bland (i.e., no sense of saltiness or sourness), their flavor intensity was low, and they had many evenly distributed holes.

Cheeses U54 and K69 were 2 of the best-liked cheeses, yet they are far from each other in Figure 1. Both cheeses were sticky and soft, but differences in their sensory profile were observed. The most remarkable differences between these 2 cheeses related to yellowness and holes (amount and deviation of holes). These cheeses had the highest salt content (Table 5). However, sample U54 tasted saltier than K69. Figure 1 reveals that cheeses K62, K91, and U41 resemble each other more. This was a group of favored cheeses that were hard, nonelastic, and slightly yellow, with a moderately rich, balanced, and intense flavor. It can be concluded that although Finnish consumers may like different types of cheeses, they display a consensus in their dislikes.

The consumers are presented in Figure 1b. Four subgroups of consumers were created by cluster analysis according to their likings. This gives more information on differences between consumers. Subgroup 1 ($n = 67$; dot) consists of consumers who prefer sour and sticky

cheese. The consumers in subgroup 2 ($n = 34$; star) prefer cheeses with an intense flavor and many holes. This group is well dispersed on the map comprising consumers with the most varying preferences. The consumers in subgroup 3 ($n = 28$; triangle) like a hard, yellow cheese. Subgroup 4 ($n = 23$; square) consists of consumers who prefer sticky cheeses with large holes. It must be stated that the groups overlap to some degree. Subgroups 3 and 4 are the furthest away from each other. Consequently, on the one side of the preference map are sticky, soft, and pale cheeses and on the other side, hard and yellow cheeses.

It is evident that more information on consumer preferences could be obtained from preference mapping than from correlations with the consumer test alone. Young et al. (2004) have created a similar preference map for Cheddar. They distinguished 6 distinct consumer segments. In addition, Lawlor and Delahunty (2000) applied preference mapping and identified consumer segments for 10 specialty cheeses. Preference mapping in the present study highlights distinct consumer segments for reduced-fat Havarti-type cheeses with varying texture; moreover, a lack of flavor was considered to be unappealing to most Finnish consumers.

CONCLUSIONS

Finnish consumers preferred reduced-fat Havarti-type cheeses with a pale appearance, sticky consistency, and rich flavor. Nevertheless, consumers could be grouped according to their preferences mainly on yellowness and consistency. The least-preferred cheeses were those with the lowest flavor intensities. Salt content correlated with overall liking. It can be concluded that the reduced-fat Havarti cheeses on the market are well liked. However, cheeses with an intense flavor but with less salt are needed to meet the need for a tasty and healthy cheese.

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