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A novel processing-based classification and conventional food grouping to estimate milk product consumption in Finnish children

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ABSTRACT

As more information is needed about the health aspects of milk processing; we classified milk products based on their homogenisation and heat-treatment history in the following inclusive classes: (i) homogenised, (ii) non-homogenised, (iii) fat-free; and (i) low-pasteurised or less heat-treated, (ii) high-pasteurised at <100 °C, (iii) high-pasteurised at ≥100 °C or sterilised. Milk product consumption of Finnish children was studied at the age of 6 months (n = 1305), 1 y (n = 1513), and 3 y (n = 1328) both using conventional food grouping and the novel processing-based grouping. At 6 months, more than three quarters of the children consumed cows' milk products (median consumption 511 g d^{-1}); at 3 y most of the consumed milk products were low-pasteurised or less heat-treated and homogenised. In contrast to children aged 3 y, almost all milk products consumed by infants aged 6 months were pasteurised at high temperature or sterilised.

1. Introduction

Different types of cows' milk products have been associated with various disease outcomes such as type 1 and type 2 diabetes and asthma (Aune, Norat, Romundstad, & Vatten, 2013; Virtanen et al., 1993; Waser et al., 2006). Thus, in addition to the type of milk product consumed, milk processing may play a role in health effects of milk. Some studies on the aetiology of diabetes and asthma have considered separately fresh milk, sour milk products, raw milk, high- and low-fat milk, and cheeses, but the processing of the milk and milk products have not been taken into account systematically. The two most important and common treatments of milk for decades have been homogenisation and heat-treatment. However, both processing methods and the consumption of differently processed milk products have changed over time.

Heat-treatment of milk is known to affect not only the microbiological characteristics of milk, but also its nutritional components such as proteins. Common heat-treatments of milk include thermalisation, low pasteurisation, high pasteurisation and sterilisation (Walstra, Wouters, & Geurts, 2006). Low pasteurisation is known to have little effect on milk composition, whereas sterilising ultra-high temperature (UHT)-treatment especially together with

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homogenisation has been observed to alter the tertiary structural stability of whey proteins (Qi, Ren, Xiao, and Tomasula (2015). Bovine immunoglobulins (IgG) have been observed to be at least partly active in low-pasteurised milk, whereas in canned evaporated and UHT-sterilised milk there has been little or no active IgG (Li-Chan, Kummer, Losso, Kitts, & Nakai, 1995). Intensive heat-treatment can also cause Maillard reactions, destroy endogenous antimicrobial systems of milk (Walstra et al., 2006), cause vitamin loss during storage (FAO, 2013) and affect the solubility of caseins (Douglas, Greenberg, Farrell, & Edmondson, 1981). Homogenisation instead breaks the milk fat globules into smaller particles so that the original phospholipid layer is substituted with milk proteins (Michalski & Januel, 2006). This changes the physiological and possibly also the biological characteristics of milk. Homogenisation has also been reported to reduce the levels of non-denaturated proteins detectable by liquid chromatography/tandem mass spectrometry in milk (Brick et al., 2017). Homogenised milk has been shown to increase the levels of milk antibodies in rats compared with non-homogenised milk (Feng & Collins, 1999). However, as far as we know, evidence of associations between milk homogenisation and untoward health effects in humans is scarce. In children allergic to milk, homogenisation did not affect the allergenic reactions (Høst & Samuelsson, 1988). Currently there is very little information on how children consume differently processed milk products.

The aims of the current study were to create a novel classification of milk products based on homogenisation and heat-treatment, and to estimate consumption of differently processed and produced milk products by Finnish infants and pre-schoolers. To gather more information about milk product consumption, we also used a conventional milk product classification to assess children's milk product consumption.

2. Subjects and methods

2.1. Subjects and study design

This study was based on data collected within the Finnish Type 1 Diabetes Prediction and Prevention (DIPP) Nutrition Study. DIPP Nutrition Study is a part of a larger DIPP Study and it sets out to assess the role of the nutrition in the development of type 1 diabetes (Virtanen et al., 2012). The genetic screening of the type 1 diabetes risk alleles was carried out in newborn infants born since 1996 in University Hospitals in Tampere and Oulu in Finland. The parents were asked for permission to examine a blood sample from the umbilical cord, from which the child's genotypes for specific HLA-DQB1 alleles were determined (Kupila et al., 2001). The children with DQB1*02/DQB1*03:02 or DQB1*03:02/x genotypes (x not DQB1*02, DQB1*03:01 or DQB1*06:02/3) were invited to a follow-up study, in which their nutrition, growth, viral infections and levels of diabetes associated antibodies were followed regularly. All the parents gave their written consent to the study.

Childhood food consumption data was collected by 3-d food records from the children recruited to the study between 1996 and 2004. In the current study, when creating the milk product classification based on processing, all food items from food records collected during the whole DIPP Nutrition Study were utilised. In the milk product consumption calculations of the current study only children born in certain years were included. We observed the food consumption at 3 different age points: at the age of 6 months ($n = 1305$), 1 y ($n = 1513$), and 3 y ($n = 1328$). The food records at the age of 6 months were from children born from 1.7.2002 to 30.6.2004, the food records at the age of 1 y from children born from 1.1.2002 to 5.9.2004 and the food records at the age of 3 y from children born from 1.1.2000 to 31.12.2002. Hence, some children can be observed at two or more of the age points. We chose the 3 age groups since we considered that there would be major changes in nutrition between the age groups – children at the age of 6 months consume mostly breast milk or infant formulas, children at the age of 1 y have already more food items in the diet and children at the age of 3 y have a diet close to that of the rest of the family.

The families completed the background information forms and food records for 3 d at the age of 3 and 6 months and 1, 2, 3, 4 and 6 y (Virtanen et al., 2012). The food records were filled out on 2 weekdays and on 1 weekend day. The food records were checked by a trained research nurse. The nurses were trained to pay attention to the type of foods eaten, whether they were homemade, commercial or from a restaurant and to check amounts of foods and drinks; what information was or was not necessary in the recording. They were educated to have knowledge of the composition of foods and dishes (brand names, recipes, and preparation and processing methods) and of dietary supplements and foods enriched with nutrients. The amounts were marked using a booklet of different portion sizes as help. For all commercial infant foods, infant formulas and dietary supplements brand names were asked.

Trained nutritionists entered the food records using the Finnish national food composition database Fineli and the in-house software Finessi of the National Institute for Health and Welfare, Finland. In the food composition database there are recipes created for food items. These recipes are based on the food item ingredients and nutrition values declared by the manufacturer or ingredient information from commonly used Finnish cookery books. The food items in the calculation process can be broken down into ingredients and hence intake of ingredients from different food items can also be summarised: thus, for example the amount of milk from foods containing milk can be calculated. The food composition database is updated annually. Most of the products consumed by the children have been recorded using the common noun for the food item, with the information of for example the food item being low-lactose and its fat percentage (e.g., cottage cheese, fat 2–5%, low-lactose). For commercial baby foods and infant formulas brand names were also known.

2.2. Principles for creating the processing-based classification

The milk products that appeared in the food records were classified as accurately as possible according to the process treatments of the milk used for the milk product. In addition to milk products, also some other food items considered as remarkable sources of milk for small children were classified. The classification was created based on homogenisation and heat-treatment. First grouping principle was the information of whether the milk product was (i) homogenised, (ii) non-homogenised or (iii) fat-free. Several fat-free products could also have been homogenised based on manufacturers' information, but since in fat-free products there are no fat globules present, on which homogenisation has the strongest impact, they were considered as their own group. Products that included fat not more than 0.5 g 100 g^{-1} or 0.5 mL 100 mL^{-1} were classified as fat-free. This limit was based on Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods.

The second grouping principle was heat-treatment: information whether the milk was (i) low-pasteurised (treated at highest for approximately 15 s at approximately 73 °C or corresponding conditions where milk alkaline phosphatase is inactivated) or less heat-treated, (ii) high-pasteurised at <100 °C or (iii) high-pasteurised at ≥100 °C or sterilised. The categories were designed to be the most accurate possible, so that the number of classes would not be too high. The exact temperature/time combinations of the products could not be known precisely and the heat-treatment history of similar products may vary, for example, depending on the manufacturer. Classes could not therefore be created more specific, so that the duration of heating could be systematically taken into account. The decision to select the three heat-treatment classes mentioned above is supported by the fact that low pasteurisation is known to cause relatively little heat denaturation of whey proteins. Milk products made of raw milk or thermalised milk in the data are so few that it did not seem to be necessary to create a separate class for them. In treatments at higher temperatures than low pasteurisation the heat denaturation of whey proteins is more significant, naturally depending on the duration of the treatment. As a lower limit of the class "high-pasteurised at <100 °C" we considered temperature/time combinations in which milk lactoperoxidase is inactivated. Heat-treatments at temperatures above 100 °C are carried out in a pressurised system due to the nature of the material (100 °C = boiling point of water). The equipment design used is therefore different from those used for heating purposes below 100 °C, which contributed to setting the limit between the second and the third group at 100 °C.

The processing-based classification of each milk product was done based on literature and information received from milk product manufacturers: collection of this information was done by collecting product information as detailed as it was available and if required, by additive questions to the major manufacturers. In making the classification we paid attention to the fact that food record data was collected in the DIPP Nutrition Study during years 1996–2004. There have been changes in the processing technologies, and hence the latest information available was not always the most correct for the years 1996–2004. We were also considering which manufacturer might have had the largest market share at the time the original food record data was collected.

2.3. Conventional classification

Since there is very little information on how infants and preschoolers in Finland consume different milk products, we wanted to present the consumption of milk and milk products not only according to the processing-based classification but also according to a more traditional classification, based on a typical categorisation of milk products. Using the recipes created in the food composition database, it was possible to separate a possible fruit component from for example yoghurts and quarks, so that we can observe only the consumption of the actual milk part of the product. Also waffles or for example chocolate part from ice creams could be separated in the calculation. Powder-based infant milks and powder-like milk products were converted to liquids using coefficients. The coefficients were calculated from the ratio between the liquid and the powder.

2.4. Statistical analyses

Using IBM SPSS Statistics 23 we studied the mean, median, SD/range of the consumption and proportion of the consumers [n (%)] of different milk products.

3. Results

3.1. Classification of milk products based on processing

The classification is presented in Table 1. Fat-free products were always classified fat-free irrespective of homogenisation. Below we will describe closer some particular aspects of the classification.

3.1.1. Liquid milk products

In Finland, most of the milk consumed is low-pasteurised and homogenised, and vitamin D is added to most liquid milks. Most of the low-lactose milks available are UHT-treated, but of standard milk only a very small proportion. Extended shelf life (ESL) -treatment is often used for special milks such as low-lactose or lactose-free milks or milks with added protein or calcium – thus they can have a longer shelf life for the added value. Both ESL- and UHT-treatments are done at temperatures higher than 100 °C, so these milks were classified in the highest heat-treatment class (Table 1).

Most of whipping creams with extended shelf life used to be UHT-treated and homogenised before starting to add carrageen in the whipping cream. Fresh whipping creams (not UHT-treated) were considered to be non-homogenised and high-pasteurised. Creams that based on their description in the database were most probably UHT-treated were classified in the highest heat-treatment class. Whipped cream was assumed to be made of standard non-UHT-treated whipping cream. According to the information by several major manufacturers (Valio Ltd, Arla Ltd, Unilever Finland Ltd) almost all cooking creams are both homogenised and UHT-treated (Table 1).

Liquid infant formulas undergo always UHT-treatment so that the product becomes sterile. Powder-like formulas can have a bigger variation in the production temperature. We classified them in the highest heat-treatment group according to milk powders (see section 3.1.2.) because based on some manufacturers' information most of the treatments were carried out at over 100 °C using spray drier (Table 1). Homogenisation was obvious since there was a vegetable oil supplement in almost all of the formulas, and homogenisation is required to distribute the supplemented fat evenly.

3.1.2. Milk powders

Powders were one of the most challenging groups of milk products to be classified. According to literature the temperatures used in the manufacturing process of milk powders can range from low pasteurisation temperatures up to much higher temperatures (Walstra et al., 2006). When manufacturing milk powder, a strong denaturation of whey proteins is not wanted since it affects the functional properties of milk powder. Normally milk reaches the highest temperature during the preheating (Kelly, O'Connell, & Fox, 2003). Milk used for whole milk powder can often be heated to 85–95 °C for several minutes (Hols & van Mil, 1991) and for milk for skim milk powder there are three principal heat categories: low heat (typically 75 °C for 15 s), medium heat (typically 75 °C for 1–3 min) and high heat (typically 80 °C for 30 min or 120 °C for 1 min) (Kelly et al., 2003). During drying the inlet air is often much higher than 100 °C, but the temperature of the milk droplet does normally not rise more than up to 70 °C. A major manufacturer in Finland uses heat-treatments at 80–120 °C and the duration ranges from few seconds to some minutes (data not shown). Based on this information we decided to classify the milk powder in the highest heat-treatment class (Table 1). Based on literature also homogenisation is possible for the manufacture process of milk powders, but most of the powders by a significant manufacturer in Finland are said to be produced without milk homogenisation.

3.1.3. Cheeses

Most ripened cheeses could mainly be classified quite simply as low-pasteurised and non-homogenised milk products, but there were some cheeses more difficult to be classified. Homogenisation information of Greek-type salad cheeses varied between manufacturers. Ultrafiltration is sometimes used for cheeses in brine (Abd El-Salam & Alichanidis, 2004). In the process of making traditional Feta cheese of sheep milk, the milk is normally thermalised or low-pasteurised and non-homogenised. In commercial production milk is often concentrated and homogenised before mixing with the starter (Banks, 2007)

Table 1
An outline of the processing-based classification of cow's milks and milk products used in Finland among children.

	Heat-treatment			Homogenization		
	Low-pasteurized or less heat-treated	High-pasteurized at <100 °C	High-pasteurized at ≥100 °C or sterilized	Homoge-nized	Non-homoge-nized	Fat-free
Non-fermented milk products						
Milks						
Standard milk	x			x		x
Raw milk	x				x	
Organic milk	x				x	x
Special milks[a]			x	x		x
Creams						
Long-lasting cream			x	x		
Fresh whipping cream		x			x	
Fresh coffee cream		x		x		
Ice creams		x		x		
Milk-based infant formulas			x	x		
Milk powders and whey powders			x		x	x
Fermented milk products						
Yoghurt		x		x		x
Viili[b]		x			x	x
Mixed seasoned viili[b]		x		x		
Standard sour milks		x		x		x
Buttermilk and organic sour milk		x			x	x
Sour creams[c]		x		x	x	
Ripened cheeses						
Semi/hard ripened cheese, mould-ripened soft cheese	x				x	
Processed cheese			x		x	
Feta	x				x	
Greek-type salad cheese		x		x		
Blue cheese	x			x		
Non-ripened cheeses						
Cottage cheese	x				x	x
Quark		x			x	x
Other fresh cheeses[d]	x			x		
Butter and butter spreads		x			x	
Foods containing milk						
Puddings			x	x		
Chocolate drinks		x		x		
Porridges and gruels			x	x		
Commercial dairy-fruit purees			x	x		

[a] Special milks: Enriched (protein, calcium) milks, lactose-free and low-lactose milks.
[b] Viili: Traditional Finnish fermented ropy milk.
[c] Russian-style sour cream smetana is non-homogenized.
[d] Includes also a traditional Finnish non-fermented cheese called "leipäjuusto".

(Table 1). However, not all ultrafiltrated Greek-type salad cheeses are homogenised, and there are differences between manufacturers. Milk for a common blue cheese is homogenised according to a major manufacturer in Finland. Lipolysis is enhanced by homogenisation, which is wanted for blue cheese. Processed cheeses go through a heating process in which the cheese mass is heated to 70–95 °C or even to 140 °C (Guinee, Carić, & Kaláb, 2004). At about 80 °C the heating lasts at least for several minutes (Walstra et al., 2006). This kind of heating was considered to alter the proteins strongly, even if the temperature might not achieve 100 °C (Table 1).

Production of soft, mild flavoured cheeses such as quark, cottage cheese and other fresh cheeses can have a lot of variation depending on the manufacturer. For example, cottage cheese can be homogenised or non-homogenised depending on the manufacturer. Quark is made of either low- or high-pasteurised milk (Schulz-Collins & Senge, 2004). The traditional production process for quark includes low pasteurisation but also many other manufacturing processes have been developed. High pasteurisation leads to bigger supply because of the heat denaturation of whey proteins and further association with casein micelles. According to a study by Vaziri, Abbasi, and Mortazavi (2010) a heat-treatment at 80 °C for 5 min is more suitable for quark manufacturing than a low pasteurisation 72 °C 16 s. A major manufacturer in Finland high-pasteurises milk for quark production (data not shown) and hence we classified it high-pasteurised (Table 1). Other fresh cheeses can be high-pasteurised or low-pasteurised.

3.1.4. Other foods and food products containing milk and being important milk sources for children

Commercial puddings were classified in the highest heat-treatment group based on information provided by a manufacturer in Finland (Table 1). Homemade cacao drink made in milk was classified in the middle group considering that milk is not heated up to the boiling point. Cold cacao drink was classified low-pasteurised according to standard, low-pasteurised milk. Babies' ready-to-use gruels and commercial purees are heat-treated to be sterile and hence they were classified in the highest heat-treatment group. As often vegetable oils are added in gruels, we considered them homogenised. Commercial porridges made of powders were classified like milk powders according to the heat-treatment. They were also classified homogenised because of the added vegetable oils. Porridges made in milk were classified like boiled milk in the highest heat-treatment class and homogenised according to standard milk: when making porridge the system is not pressurised and the temperature of the milk does not quite reach 100 °C, but the milk stays at the boiling point or close to it for several minutes.

Table 2
Consumption of milk products by Finnish children by age according to conventional classification.[a]

Product	6 months (n = 1305)		1 y (n = 1513)		3 y (n = 1328)	
	Users (%)	Users' median consumption (g d^{-1}) (IQR)	Users (%)	Users' median consumption (g d^{-1}) (IQR)	Users (%)	Users' median consumption (g d^{-1}) (IQR)
Non-fermented milk products	76.5	509 (127–707)	92.8	561 (370–715)	97.9	458 (313–601)
Milk	49.3	49 (21–84)	86.1	248 (100–462)	97.2	417 (285–563)
Cream	23.1	1 (1–2)	51.3	3 (1–7)	66.0	9 (4–18)
Ice cream	1.5	2 (1–4)	16.6	7 (2–11)	56.6	17 (10–30)
Infant formulas	61.5	443 (213–589)	51.5	350 (195–516)	0.5	61 (17–220)
Milk-based non-protein hydrolysed	58.5	433 (210–583)	46.2	333 (179–498)	0.4	39 (17–148)
Milk-based protein hydrolysed	2.9	525 (240–716)	4.4	553 (390–667)	0.1	–
Powder-like milk protein containing preparations	64.7	106 (53–168)	65.3	93 (25–181)	56.9	8 (2–22)
Fermented milk products	17.8	8 (5–14)	82.9	59 (20–107)	94.1	74 (35–139)
Yoghurts and fermented milks	16.8	8 (6–16)	69.3	65 (33–110)	72.5	85 (44–142)
Sour creams	0.0	–	5.5	2 (1–6)	13.0	4 (2–8)
Ripened cheese	0.3	2 (1–4)	37.3	3 (2–7)	79.7	10 (4–18)
Non-ripened cheese	1.0	2 (1–3)	36.9	4 (3–10)	35.2	8 (3–17)
Total: All cows' milk products	76.5	511 (133–710)	93.8	626 (433–777)	98.1	555 (401–701)

[a] Abbreviation: IQR, interquartile range (value given in parentheses). Yoghurts and fermented milks includes traditional Finnish fermented ropy milk 'viili' and sour milks; non-ripened cheese includes also a traditional Finnish non-fermented cheese called "leipäjuusto" and quarks.

Table 3
Consumption of milk products by Finnish children by age according to processing-based classification.[a]

Product	6 months (n = 1305)		1 y (n = 1513)		3 y (n = 1328)	
	Users (%)	Users' median consumption (g d^{-1}) (IQR)	Users (%)	Users' median consumption (g d^{-1}) (IQR)	Users (%)	Users' median consumption (g d^{-1}) (IQR)
Homogenisation:						
Homogenised	63.8	407 (117–574)	89.7	391 (191–583)	96.8	315 (158–502)
Non-homogenised	59.5	75 (27–144)	89.7	37 (7–143)	97.7	26 (13–53)
Fat-free	62.4	64 (29–109)	78.7	95 (38–206)	85.2	141 (35–319)
Heat-treatment:						
Low-pasteurised or less heat-treated	1.7	1 (0.5–23)	85.5	153 (32–366)	97.1	347 (212–495)
High-pasteurised at <100 °C	6.4	1 (0.2–2)	86.6	62 (15–113)	98.1	103 (50–179)
High-pasteurised at ≥100 °C or sterilised	76.1	514 (134–713)	87.8	314 (139–541)	86.8	62 (21–128)

[a] Abbreviation: IQR, interquartile range (value given in parentheses).

3.2. *Conventional classification*

Conventional classification is based on commonly used milk product groups such as milks, creams, ice creams, yoghurts, etc. This classification is presented in Table 2.

3.3. *Milk product consumption by Finnish children*

3.3.1. *Consumption according to conventional classification*

About half of the children consumed cows' milk at the age of 6 months (Table 2). More than a fifth of the children at the age of 6 months used cream, but the median consumption of users was only 1 g d^{-1}. This might be explained by the fact that some of the commercial baby foods included cream. Cows' milk -based non-protein hydrolysed infant formulas were used by 58.5% of the children and the median consumption of the users was 433 g d^{-1}. The proportion of users of cows' milk increased by age. At the age of 1 y the amount of milk consumed was 5 times higher than at the age of 6 months. Also, the number of users of different types of milk products such as ice creams and cheeses was higher in older age groups. At the age of 3 y the consumption of cows' milk products was on an average a little smaller than at the age of 1 y.

3.3.2. *Consumption according to processing-based classification*

At the age of 6 months homogenised, non-homogenised and fat-free products were each consumed by about 60% of children (Table 3). Most of the milk products consumed were homogenised. Consumption of fat-free products increased by age. Almost all of the children at the age of 3 y were consuming homogenised and non-homogenised milk products. Fat-free products were consumed by 85% of children. Children at the age of 6 months were consuming mostly high-pasteurised at ≥100 °C or sterilised milk products. This can possibly be explained with the consumption of infant formulas, which are all classified as sterilised. Milk products of other heat-treatment groups were hardly used. At the ages of 1 y and 3 y the consumption of low-pasteurised milk products was significantly higher than at the age of 6 months.

4. Discussion

In this study, we classified milk products based on literature and manufacturers' information on milk processing (heat-treatment, homogenisation) conditions (Table 1). Using food records collected during several years we observed that children's milk product consumption varied by age according to both conventional and the novel processing-based classification created in the current study. Children at the age of 6 months consumed mostly strongly heat-treated milk products. Most of the milk products consumed by children in all age groups were homogenised (Table 3).

At the age of 6 months, the consumed milk was mostly in the form of infant formula. More than 60% of the children received infant formulas at the age of 6 months (Table 2), which shows that recommended exclusive breastfeeding until 6 months did not come true in Finland. WHO (2001) recommends that infants should be exclusively breastfed for the first 6 months of life. Many children had consumed cows' milk at the age of 6 months. The milk was not necessary taken as a liquid but could be received from gruels, porridges or other baby foods. Victora et al. (2016) reported that in low-income and middle-income countries, only 37% of children younger than 6 mo of age are exclusively breastfed and in high-income countries the duration of exclusive breastfeeding is even shorter.

At the age of 1 y, consumption of cows' milk was close to 250 g d^{-1}, and the proportion of children consuming milk was higher than the proportion of children consuming infant formulas. More than 97% of children consumed cows' milk at the age of 3 y and the mean consumption was 418 g of milk d^{-1}, almost the same as the median consumption 417 g milk d^{-1} (Table 2). The mean as well as median consumption of hard, ripened cheeses was 10 g d^{-1}. The milk product consumption changes remarkably in the first 3 y of life. It has been reported earlier for years 2003–2005, that in Finland children at the age of 1 y consume a lot of porridge and the diet often includes commercial baby foods (Kyttälä et al., 2010). Children's diet at the age of 3 y has already many things in common with the diet of the rest of the family. In the current study, consumption of fat-free products increased by age.

In Finland the recommendation of milk product consumption for pre-schoolers is 400 mL of liquid milk products and 1 slice of cheese per day (NNC, 2016). Starting from school age the recommendation for all family members is 500–600 mL of liquid milk products and 2–3 slices of cheese per day. It is recommended to choose low-fat or fat-free milk products. The former recommendations, which were valid at the time of the collection of the current data, were recommending 500–600 mL d^{-1} of milk for preschoolers (Hasunen et al., 2004). According to this study the median consumption for users of milk products at the age of 3 y, 555 g d^{-1}, is within the prevailing Finnish recommendation.

There are few studies on the milk product consumption by children in other countries. In a French study it was reported that in the data collected 2006–2007 children at the age of 3–10 y consumed on average 197 g milk, 87 g of cream, yoghurt and some fresh cheeses, and 19 g of other cheeses per day (Lioret et al., 2010). In a German study (data from 1986 to 2001) the average consumption of milk products was 283 g d^{-1} for children at the age of 1–3 y (Alexy & Kersting, 2003). Hence, in our study Finnish children consumed more liquid milk products than children in France and Germany. Dror and Allen (2014) have reviewed the milk product consumption by preschool children from several countries. According to the review, milk product consumption was about 420 g d^{-1} in Australia at 2–3 y of age, 635 g d^{-1} in Singapore at 3–6 y of age, and less than 150 g d^{-1} in South Africa (Dror & Allen, 2014). In United Kingdom the average consumption of milk, yogurt, fresh cheeses and dairy desserts was about 220 g d^{-1} and consumption of cheeses about 8 g d^{-1} at the age of 1.5–3 y. Somewhat surprisingly the reported milk consumption in Belgium, i.e., more than 500 g of milk d^{-1}, was substantially higher than in France and Germany and also a little bit higher than in Finland, median 417 g d^{-1} at 3 y (Table 2). Among the listed countries, the Finnish consumption of milk products is anyhow one of the highest.

The recommendation in Belgium (Flanders) – 3 servings of milk products and 1 serving of cheese per day (1 serving = 150 mL milk/yoghurt/fermented milk drinks/custard or 20 g cheese (<20% fat by weight)) (Dror & Allen, 2014) is also similar to the Finnish recommendation for preschoolers. In France it is recommended to have 3–4 servings per day (1 serving = 150 mL milk/125 g yoghurt/30 g cheese). The French recommendation differs from the Finnish one, with a stronger emphasis on cheese. In Finland, milk has been traditionally an important drink and it is often served as part of a meal not only in kindergartens and schools but also in canteens and lunch rooms. It must be noticed that in our study also milk from foods was included in the amount of milk consumed which may partly explain the higher consumption in Finland. The results derived from the processing-based classification we cannot unfortunately compare to published data, since a similar classification based on milk product processing has not been performed previously according to our knowledge.

A major strength of this study is the population-based design with a large data set of food consumption (DIPP Nutrition Study). Another strength is the use of the regularly updated national food composition database Fineli, which includes a large amount of food items that can also be broken down into ingredients. This basis gave us good possibilities to observe milk product consumption by Finnish children. A major limitation of this study was that the classification of milk products based on their processing was not unambiguous. Different manufacturers could have given different information about processing of similar milk products. Also, different literature sources could differ from each other. Thus, we had to make assumptions in the classification of milk products. Especially the classification of milk powders was challenging, the heat-treatment can vary significantly and it was impossible to separate differently heated milk powders in the data. Still the protein denaturation was expected to be of such extent that according to our consideration the powder would almost in all cases belong to one of the two highest heat-treatment groups. Another source of possible error came from the food composition database: the food records contained dishes consisting of recipes, and hence part of the milk received from dishes could have been classified in a wrong heat-treatment class. If milk has been used in for example oven-baked macaron casserole, it should be in the highest heat-treatment class, but in the food calculation process it breaks to normal milk which is classified low-pasteurised. The food data are, however, so extensive that we believe that these kinds of small inaccuracies do not significantly change the results.

Especially the children at the age of 6 months consumed mostly strongly heat-treated milk products. At the age of 3 y the consumption of strongly heated milk products was relatively modest, and mostly low-pasteurised milk products were consumed (Table 3). Low-pasteurisation is known to have few effects on milk components, whereas UHT-treatment induces several changes in milk. A strong heat-treatment causes for example whey protein denaturation and reduces solubility of caseins in milk (Douglas et al., 1981). Qi et al., (2015) reported that there were significant changes in the tertiary structural stability of whey proteins in UHT-treated milk. It is hence interesting to notice that especially infants consume mostly strongly heat-treated milk products that might have different immunological properties than those of less heated milk products.

In all three observed age categories, most milk products consumed were homogenised, which was not a surprising result considering that practically all yoghurts and most milks and infant formulas are homogenised (Table 3). The effects of homogenisation are widely discussed. Brick et al. (2017) reported that not only heat-treatment but also homogenisation causes significant changes in milk proteins. Their study suggests that the higher amount of heat-sensitive proteins in raw milk compared with treated milk makes the proteins of raw milk potential candidates for protecting against asthma and allergies. Homogenisation and heat-treatment together can also have some effects only occurring when they both are carried out; β-lactoglobulin and α-lactalbumin have been noticed to adsorb on a homogenised fat globule only if the fat globules were heated at temperatures >70 °C before homogenisation (Sharma & Dalgleish, 1993).

5. Conclusions

This study shows that Finnish children consume quite high amounts of cows' milk compared with children from other developed countries. Especially children at the age of 6 months consume a lot of homogenised and strongly heat-treated milk. The present novel processing-based classification makes it possible to study in the future whether the milk processing might explain some of its associations with different disease outcomes, such as the risk association between milk consumption and the development of type 1 diabetes, and on the other hand the protective association of farm milk in relation to children's asthma reported in some earlier studies.

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