Comparison between conventional (animal origin) milk and milk from plant kingdom

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Abstract

Plant-based milks are an emerging market, often used as a substitute to bovine milk. The purpose for choosing a plant-based milk can be due to medical reasons such as milk-protein allergy and lactose intolerance. Lifestyle choices such as a thrive towards a vegan diet can be another factor. The aim with this literature study was to compare bovine milk with two common plant-based milk: soy milk and oat milk; as well as exploring future perspective for plant-based milk.

Plant-based milks are suspensions of disintegrated plant-materials in water which resemble the white opaque appearance of bovine milk. All the product processes include some type of a heat treatment to ensure a safe product.

Nowadays, the climate changes is one of the major topics discussed and the environmental impact of our diet are of interest. The opinion is that the bovine milk gives rise to the highest greenhouse gas emission whilst oat stands for the lowest. However, when comparing greenhouse gas emission with the nutrient density of the products, bovine milk is superior to soy and oat. Many factors, such as protein content and quality, vitamins and minerals, are involved when comparing the nutritional aspects of the product. But it could be concluded that they differ extensively regarding protein quality and content. Plant-based milks should not be used as a substitute for bovine milk without insight in these dissimilarities, but as a complement.

Keywords: bovine milk, plant-based beverages, plant-based milk, environmental impact, nutritional value, comparison, production process
Sammanfattning


Växtbaserad mjölk är en suspension av sönderdelade växter i vatten och efterliknar mjölks vita utseende. Alla tre produktionsprocesserna inkluderar olika värmebehand- ligar för att uppnå ett säkert livsmedel.


Nyckelord: komjölk, växtbaserad dryck, växtbaserad mjölk, miljöpåverkan, närings- innehåll, jämförelse, produktionsprocess
Table of contents

Abbreviations 4

1 Introduction 6
1.1 Background 6
1.2 Aim 7
1.3 Method 7

2 Production process 8
2.1 Processing of bovine milk 8
2.2 Processing of oat milk 9
2.3 Processing of soy milk 10

3 Environmental impact 12
3.1 Global warming potential 12
3.2 Nutrient Density to Climate Index 13

4 Nutritional aspects and bioactive compounds 14
4.1 Nutritional information 14
  4.1.1 Vitamins 14
  4.1.2 Fat 16
  4.1.3 Carbohydrates 17
  4.1.4 Proteins 18
  4.1.5 Fortification 19
4.2 Bioactive compounds 20
  4.2.1 Bovine milk 20
  4.2.2 Oat milk 20
  4.2.3 Soy milk 21

5 Future perspective for plant-based milk 22

6 Discussion 23

References 25
Abbreviations

CVD = Cardiovascular disease
EFSA = European Food Safety Authority
FA = Fatty acid
GHG = Greenhouse gas
LOX = Lipoxygenase, enzyme in soy beans
NDCI = Nutrient Density to Climate Index
NNR = Nordic Nutrient Recommendations
PDCAAS = Protein digestibility-corrected amino acid score
PRP= Proline rich polypeptide
PUFA = Poly unsaturated fatty acid
UHT = Ultra-high-temperature treatment
25(OH)D = 25-hydroxyvitamin D
1 Introduction

1.1 Background

The consumption of bovine milk is widespread throughout the world. Milk is a source of all macro nutrients and has been used since early civilizations (Nylander et al., 2014). Nowadays, plant-based alternatives to milk have gained more of the consumers’ attention resulting in a growing market (Sethi et al., 2016).

Statistics for Sweden ranging from 1980 to 2016 shows a decrease in total consumption of bovine milk, the average person consumed 109 litres of milk/year in 2016, compare to 185 litres of milk/year in 1980 (Eidstedt, 2017). Overall, the production of dairy products have increased in EU, however the consumption of drinking milk has decreased (AHDB, 2016). Oat, followed by soy and almond are the major plant-based milks sold in Sweden and increased sale of plant-based milks has been reported (Sonck, 2017).

The reasons for choosing a plant-based milk can be diverse. One can be the lack of lactose, which is the main carbohydrate in bovine milk. Lactose is a disaccharide composed of galactose and glucose (Johnson & Conforti, 2003). The enzyme lactase hydrolyses lactose to monosaccharides and lack of this enzyme results in lactose intolerance (Vuorisalo et al., 2012). As mentioned, lactose intolerance is one of the factors contributing to consumers choice in plant-based milk alternatives. Another factor is milk protein allergy (Nylander et al., 2014). This problem is more common among infants affecting around 0.5 - 3.5 %. However, 80 % of the children outgrow their allergy before turning 16 (Gray et al., 2015; Hochwallner et al., 2014).

Besides medical aspects, a thrive towards a vegan or vegetarian diet contributes to a choice in a plant-based milk. Environmental and health aspects can also be a reason for implementation of a vegetarian diet, thus making the segment of plant based milks more attractive (Van Winckel et al., 2011).

The use of the word milk for describing beverages derived from plant kingdom can contradict with the definition of the word milk produced by different animal
species. The definition of animal based milk is “An opaque white fluid rich in fat and protein, secreted by female mammals for the nourishment of their young” (Oxford, 2018). However, nowadays the definition also includes “The white juice of certain plants” (Oxford, 2018). Therefore, the term milk, even for plant-based products will be used in this thesis, e.g. oat milk and soy milk. However, on the Swedish market, the word milk is not allowed to be use on plant-based drinks due to European legislation (Europaparlamentets och rådets förordning (EU) nr 1308/2013).

1.2 Aim

The aim of this thesis is to compare bovine milk with plant-based milk processed from soy and oat. Following questions will be answered:

- Productions process for the milks
- Environmental impact
- Nutritional value and effects on human health
- Future perspective for plant-based milks

1.3 Method

This literature study has been conducted by searching for scientific articles, books, reports and statistic through scientific databases such as Web of Science, Google Scholar, PubMed. Also, the search engine Primo, from the library of SLU have been used to single out relevant material.

Following search terms have been used in several variations: milk, bovine, cow, oat*, soy, “plant based”, processing, “health effects”, health, nutrition*, beverage, drink, dairy*, products, bean*, production, environmental, “climate change”, protein, PDCAAS, nutrition*.

Rules and legislations were searched from authorities’ websites like Swedish Food Agency and WHO.
2 Production process

2.1 Processing of bovine milk

Depending on the desired product, the milk entering the diary plant is treated differently. Due to milk being perishable, further treatments of the raw material are needed to accomplish a product with longer shelf life and good hygiene standards (Nylander et al., 2014).

The 4 °C milk is entering the dairy plant and heated to 60°C to facilitate the next step: separation. Separation of the milk aims to remove solid impurities and divide the cream and skim milk into two fractions. Around 4% of the milk consists of milk fat globules. The aqueous phase (87-88%) have disperse particles e.g. casein micelles (approximately 2.5%), solved constituents such as whey proteins (0.8%) and lactose (4.6%). The raw milk is lead in to the separator, which is a type of centrifuge where the work of action is based on Stokes law. During the centrifugation, the skim milk moves outwards to the edge of the machine and the less dense milk fat globules - cream, stay in the middle of the centrifuge and are pressed upwards. The cream has a fat content around 40% whereas in the skim milk contains less than 0.05% fat. These two fractions are withdrawn in two different flows (Kutz, 2013).

Standardization is performed to ensure that the precise fat content will be achieved for the given product. The cream is diluted with the skim milk until wanted content of fat is received. Milk with a fat content of 0.1%, 0.5%; 1.5%; 3% are commonly offered on the market in Sweden (Nylander et al., 2014).

Next in the production process is homogenization. The main aim with this processing step is to prevent creaming. Creaming is the natural process occurring in non-homogenised milk, where the milk fat globules rise to the surface creating a

\[ V_s = \frac{(2/9)r^2g}{\eta} \left( \frac{p_p-p_f}{\eta} \right) \]

Where \( r \) = particle radius, \( \eta \) stands for the fluid viscosity, \( V_s \) is the particle’s settling velocity, \( g \) stands for acceleration of gravity, \( p_p \) is the density of the particle and \( p_f \) is the density of the fluid (Cheremisinoff, 2016).
layer of cream. By heating the milk to around 60 – 70°C at a pressure of 10-20 MPa and then pressing it through small orifice, the milk fat globules will be smaller with more standardized size and higher density. This results in more evenly distributed fat globules, which will not cluster together. One other positive effect of homogenisation is that the milk is whiter and a richer mouthfeel. However, homogenization reduces the milk's ability to syneresis. For consumption milk, a cream milk with a fat content of 10% is mixed and homogenized before standardisation with the non-homogenized skim milk. Therefore the milk for consumption is often a partly homogenized product (Nylander et al., 2014).

Straight after homogenization the pasteurization is performed. It is a heating step with the purpose to eliminate microbial hazards and spoilage organisms like bacteria and viruses but also to reduce the activity of enzymes which could affect the product quality in a negative way and reduce the shelf-life. All milk is pasteurized to prevent any spread of disease. Different times and temperatures can be used to obtain the desired effect of the pasteurization, a commonly used way is to treat the milk at a temperature of 72°C at 15 seconds, frequently called low pasteurisation. Products with higher percentage of fat need to be treated at higher temperatures or longer time due to low ability of the fat to conduct heat. Ultra-high-temperature treatment (hereafter entitled UHT) is a pasteurisation method where high temperature, 135-140°C, and larger pressure is applied (Nylander et al., 2014). This treatment is so effective that even spore forming bacteria is eliminated, resulting in a product with long shelf life even at room temperature if aseptically packaged. Some of the drawbacks of UHT treatment is that the flavour is affected and protein denaturation can occur (Gedam et al., 2007). UHT milk have a longer shelf life and can be stored around 5 months in room temperature (Foods, 2019).

Bovine milk in Sweden must be enriched with vitamin D which is added to the milk (The Swedish National Food Agency, 2017). The shelf-life is stated to 7 days (Mellanmjölk 1,5%, 2019).

2.2 Processing of oat milk

Approximately 60% of the oat kernels consist of starch (Zhu, 2017). The high percentage of starch has positive impact on e.g. the mouthfeel of oatmeal, however it entails problems during the production process of oat milk. Gelatinization of starch occurs in a temperature range of 44.7-73.7°C. Subsequently, heat treatment induce gelatinization of starch leading to a beverage with gel like consistency (Sethi et al., 2016). To overcome this problem hydrolysis of starch is one way to get a milk that can withstand the heat treatment. By addition of amylases, conversion of starch into maltodextrins can occur and gelatinization can be avoided. Another effect of the
hydrolysation is that the beverage receives a sweeter taste without the addition of any sweeteners. By enzymatic hydrolysation the yield can be improved, Deswal et al. (2014) showed that an enzymatic concentration of 2.1% (w/w) resulted in the highest yield and best rheological parameters of the milk. Swedish oat milk producer, Oatly (2018b), implements a production method with enzymatic degradation of starch.

The production process starts with oat kernels and water. The two components are grinded until smaller particles are obtained (Deswal et al., 2014; Dahllöv & Gustafsson, 2008). The slurry is thereafter treated with α-amylase and β-amylase for degradation of the starch content. The mixture is next filtered to separate unwanted fractions like the bran and other insoluble fibres. This filtration results in a milk like consistency of the product. Soluble fibres such as β-glucans remains in the oat milk. Centrifugation is an alternative to filtration and results in the same outcome since the supernatant easily can be removed. The part which is not used in the oat milk production, like bran and insoluble fibres, can be used for bio gas production. After the separation additives, such as calcium phosphate and calcium carbonate, vitamins for enrichment and salt are added. The commercially available oat milks then undergo UHT treatment to achieve an inhibition of microbial hazards resulting in a prolongation of the shelf life. The products often come in tetra packs and is kept cold once opened (Deswal et al., 2014; Dahllöv & Gustafsson, 2008). The shelf-life is 365 days from production date if not opened. Once opened, it has to be consumed within 5 days (Oatly Havredryck, 2019).

2.3 Processing of soy milk

The use of soybean and its products, milk included, range back in time before Christ. In Eastern countries it has been a significant source for protein and energy long before Western countries started to incorporate it in the diet (Giri & Mangaraj, 2012).

The milk extracted from the whole soybean holds similar properties as traditional milk from cow regarding physical assets. The soy milk is extracted by soaking beans in water overnight, followed by wet grinding and boiling for enhancement of flavours and nutritional aspects. Last the mixture is filtered leaving two components - the milk and okra. Okra contains fibres that are unwanted in the milk. These basic steps are still often used, although new ways of production are incorporated in the process. This old method, called cold-grind, results in a milk with desirable mouthfeel but with a rancid smell which makes it unappealing as a cold beverage (Giri & Mangaraj, 2012). The rancid smell is due to the activity of the enzyme lipoxygenase (LOX). LOXs are present in a variety of plants, however the content in soybean is
very high. The enzymes acts on the unsaturated fatty acids in the bean, like linoleic acid, resulting in the unwanted flavour (Murphy, 2008).

Fujimaki et al. (1965) showed, that the lipid oxidation could be linked with the formation of volatile carbonyl compounds like \( n \)-Hexanal. Other aldehydes and volatile compounds such as esters and alcohols are also result of the enzymatic activity on polyunsaturated fatty acids (PUFA) and esters (Liu, 2008) Thus, the action of LOXs needs to be inhibited in the production process to get a desirable product. Other methodologies as hot-grinding, hot-blanch and Canadian airless cold-grind (Giri & Mangaraj, 2012) have therefore been developed but cold-grinding is most commonly used (Giri & Mangaraj, 2012).

- **Hot-grinding** - the step for wet grinding is conducted in hot water and steam. The pH is increased by the addition of \( \text{HCO}_3^- \). Combining the two factors helps to inhibit the activity of LOX, though this process makes the proteins of the soybean insoluble resulting in a chalky mouthfeel and a loss of yield.

- **Hot-blanch** - this method improves the above-mentioned method, but the beans are blanched in hot water or alkaline solutions. This inactivates the LOXs completely, however the problem with insoluble proteins are still present and the product obtains a roasted nut flavour.

- **The Canadian airless cold-grind** - by removing the oxygen needed for the LOX to catalyse the oxidation of lipids, the grinding can be done like the traditional cold-grind, resulting in the smooth mouthfeel but without the off-flavours causing by volatile compounds.

Nowadays, commercial soy milk undergoes final processing steps like homogenization and pasteurization to obtain a safe product with long shelf-life. Also, the addition of sweeteners and different flavouring makes the modern soymilk more desirable and accepted around the world (Liu, 2008). The milk is often fortified with minerals, e.g. calcium. After pasteurization of the soy milk, it is reheated to 50 °C and a sequestering agent, which prevent further enzymatic reaction, is added. The milk is mixed for 10 minutes before fortification with calcium salts is done. A final heating step to 70 °C is conducted before addition of a stabilizing agent and a calcium fortified milk is obtained (Sethi et al., 2016). Shelf-life for the product is 180 days if kept closed and within 5 days once opened (Sojadryck original Alpro, 2019).
3 Environmental impact

The human impact on the environment has contributed to one of our times major obstacles, global warming and climate changes (McMichael *et al.*, 2007). Our food production systems are a major post in the total greenhouse gas (GHG) emission (Burney *et al.*, 2010). In EU 29% of the emissions are thought to come from the agricultural sector and food chain (Makinen *et al.*, 2016). Therefore, sustainable solution in the agricultural sector are necessary as well as changes in dietary patterns (Röös *et al.*, 2016).

3.1 Global warming potential

One way how to measure different food products and their effect on the environment is the measurement of emission of CO₂ equivalents (CO₂-eq). CO₂-eq emissions for bovine milk, oat milk and soy milk, estimated for their life cycle, are presented in table 1.

<table>
<thead>
<tr>
<th>Product</th>
<th>CO₂-eq/kg product</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovine milk</td>
<td>0.84-1.30</td>
<td>de Vries and de Boer (2010)</td>
</tr>
<tr>
<td>Oat milk</td>
<td>0.21</td>
<td>Makinen <em>et al.</em> (2016)</td>
</tr>
<tr>
<td>Soy milk</td>
<td>0.31</td>
<td>Makinen <em>et al.</em> (2016)</td>
</tr>
</tbody>
</table>

As presented in table 1, oat milk has the lowest climate impact followed by soy milk. Bovine milk gives a considerably higher climate impact compared to the plant-based alternatives. Available studies assess the plant-based alternatives conclude that when solely looking at GHG emissions, the plant-based alternatives have lower climate impact than bovine milk (Makinen *et al.*, 2016).
3.2 Nutrient Density to Climate Index

Comparing the products only based on GHG emissions can be misleading since the nutritional profile differs extensively. Smedman et al. (2010) present a method that compare the climate impact in relation to nutrient density, called the Nutrient Density to Climate Index (NDCI). The nutrition density is based on Nordic Nutrient Recommendations (NNR) and divided by the climate impact; see formula 1 (Smedman et al., 2010).

Formula 1. Equation for calculation of Nutrient Density to Climate Index (NDCI)

\[
NDCI \ index = \frac{\text{Nutrient density of } Y}{\text{CO}_2 \text{ eq for } 100 \text{ g of } Y}
\]

Tabell 2 Nutrient Density to Climate Index (NDCI)-index for bovine milk, oat milk and soy milk, summarized from Smedman et al. (2010)

<table>
<thead>
<tr>
<th>Product</th>
<th>NDCI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovine milk</td>
<td>0.46</td>
</tr>
<tr>
<td>Oat milk</td>
<td>0.07</td>
</tr>
<tr>
<td>Soy milk</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*The NDCI-index is based on unfortified products since information about the GHG emission on the fortified plant-based milks was not available (Smedman et al., 2010).

Comparing the specific products with emphasis on NDCI, bovine milk scores highest, see table 2, while oat milk scores lowest. Obtaining a high index is favourable. The high nutrient density for bovine milk gives a high score even if the GHG emissions is high, oat, on the other hand scores low even if the GHG emission for the product is low. This could be explained by the low amounts of many nutrients e.g. proteins (Smedman et al., 2010). Soy milk scores higher than oat milk due to its more favourable nutritional value. However, soy milk compared to bovine milk scores lower. Bovine milk is the most preferable when comparing GHG emission to nutrient density.

Milk production requires more land than the production of plant-based alternative (Röös et al., 2016). However, milk producing ruminants are straight connected to grazing, which results in a number of ecosystem benefits i.e. preserving biodiversity and cultural landscapes but also meat production (Robert Kiefer et al., 2015). Ruminants also can utilize grass biomass that are not suitable for human consumption (Röös et al., 2016). Also, the fact that bovine milk contains essential nutrients which are difficult to replace, makes the comparison regarding environmental factors complex (Makinen et al., 2016).
4 Nutritional aspects and bioactive compounds

4.1 Nutritional information

4.1.1 Vitamins

Plant-based milks can be considered as alternative to bovine milk as the appearance and texture is intended to be similar. If a food product has been recognised as an important source of energy and essential nutrients, it should follow the recommendation from Codex Alimentarius\(^2\). Any alternative, in this case plant-based milks, are highly recommended to meet the essential nutritional parts associated with the food stuff, in this case bovine milk (Sethi \textit{et al.}, 2016).

As seen in Table 3 the bovine milk has the highest energy content followed by oat milk and soy milk. The energy origins from the different macronutrients and in oat milk mainly from carbohydrates. In bovine milk and soy milk the energy is more evenly distributed between fat, protein and carbohydrates.

The milks compared in Table 3 are the fortified versions and therefore there are no larger differences regarding vitamin D, B\(_2\) and B\(_{12}\) between these products. One important difference is also that the soymilk lacks vitamin A. Both Swedish brand Oatly and the Belgium brand Alpro fortificate their product Havredyrck and Alpro Soja Original with calcium, vitamin D\(_2\), B\(_2\) and B\(_{12}\) (Oatly., 2018a; Alpro.). Since

\(^{2}\) An international food standard (FAO., 2018)
B12, and calcium are nutrients that could be limiting factors in a vegan and vegetarian diet (Sebastiani et al., 2019), fortification helps to resemble the nutrient values of the bovine milk and counteracts deficiencies.

Tabell 3. Nutritional composition of bovine milk (1.5% fat), oat drink ready-to-drink, and soy beverage (The Swedish National Food Agency, 2017b)

<table>
<thead>
<tr>
<th>Nutritional information (100 g)</th>
<th>Bovine milk (1.5% fat)</th>
<th>Oat milk</th>
<th>Soy milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong> (kcal)</td>
<td>47</td>
<td>42</td>
<td>37</td>
</tr>
<tr>
<td><strong>Energy</strong> (kJ)</td>
<td>198</td>
<td>174</td>
<td>154</td>
</tr>
<tr>
<td><strong>Fat</strong> (g)</td>
<td>1.5</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Saturates (g)</td>
<td>0.96</td>
<td>0.09</td>
<td>0.15</td>
</tr>
<tr>
<td>Mono-unsaturated (g)</td>
<td>0.37</td>
<td>0.55</td>
<td>0.26</td>
</tr>
<tr>
<td>Polyunsaturated (g)</td>
<td>0.04</td>
<td>0.32</td>
<td>0.61</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>4.9</td>
<td>7.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Sugar total (g)</td>
<td>4.9</td>
<td>3.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td><strong>Proteins</strong> (g)</td>
<td>3.57</td>
<td>0.35</td>
<td>2.57</td>
</tr>
<tr>
<td><strong>Salt</strong> (g)</td>
<td>0.10</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Vitamins</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin D (µg)</td>
<td>1.00 (20%) *</td>
<td>1.62 (32.4%) *</td>
<td>0.74 (14.8%) *</td>
</tr>
<tr>
<td>Vitamin A (µg)</td>
<td>13.8 (1.7%) *</td>
<td>36.3 (4.5%) *</td>
<td>0.00 (0 %) *</td>
</tr>
<tr>
<td>Vitamin B12 (mg)</td>
<td>0.15 (10.7%) *</td>
<td>0.24 (17.1%) *</td>
<td>0.21 (15%) *</td>
</tr>
<tr>
<td>Vitamin B12 (µg)</td>
<td>0.59 (23.6%) *</td>
<td>0.46 (18.4%) *</td>
<td>0.38 (15.2%) *</td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>163 (20.4%) *</td>
<td>120.0 (15%) *</td>
<td>96.5 (12.1%) *</td>
</tr>
</tbody>
</table>


Regarding the content of vitamin D, as seen in Table 3, one need to take under consideration that vitamin D can occur in different forms, namely D2 and D3, where D3 has the only structure naturally present in food. This is also the form obtained when UV-light converts the intermediate 7-dehydrocholesterol to D3 in the epidermal cells of the skin (Coultate, 2016).

D3 used for enrichment are extracted from the fat of sheep’s wool, thus origins from animal kingdom making it not apposite for vegans. D2 is derived from ergosterol, a compound found in the cell wall of mushrooms. It can be synthesised in
large scale making it suitable for enrichment of products that need a vitamin D source origin from plant kingdom (The Swedish National Food Agency, 2018b), such as soy milk and oat milk. Nonetheless, the biological activity differs between the two forms (Abrahamsson et al., 2006). The marker of vitamin D status in the body is the level of 25-hydroxyvitamin D (25(OH)D) also known as calcifediol, which is a prehormone produced in the liver by hydroxylation of vitamin D₃. A study conducted by Tripkovic et al. (2017) emphatically displays that the efficiency of D₃ is more than double compared to D₂ regarding the ability to increase the levels of 25(OH)D. Since there is a difference between the two forms, it needs to be taken under consideration during the processing and vitaminisation. Since milk is enriched with vitamin D₃, it is an important source of the essential micronutrient important for our health (Abrahamsson et al., 2006). However, the bioavailability of the vitamins and minerals used to enrich the products can vary depending of source and production processes (Makinen et al., 2016).

4.1.2 Fat

Bovine milk

The fat content 1.5 %, see Table 3, in the most common milk quality, consists of mostly fatty acids (FA) between the length of 4 to 18 C atoms (Walstra et al., 2005). Fat in bovine milk is one of the most complex once in our diet with a wide range of more than 400 different FA. Thus, several of the FA obtained by consuming dairy products are not found elsewhere in our foods (Kratz et al., 2013). The degree of saturation is around 70 mol % and the FA patterns include a high proportion of short FA ranging from 4-10 carbons (Walstra et al., 2005).

The FA composition can vary depending on e.g. the cows feed, stage of lactation and genetics (Walstra et al., 2005).

Many studies have assessed the negative connection between dairy fat and cardiovascular disease (CVD). However, when taking all of these studies in to account, there is no support for this statement (Kratz et al., 2013). On the contrary, some of the FA in milk are thought to have beneficial effects on human health and possibly lower the odds of overweight (Brouwer-Brolsma et al., 2018). When looking on bovine milk consumption in specific, no positive association between overweight and bovine milk consumption could be found in a numerous of studies. However one study observed a positive association between overweight and consumption of semi-skimmed milk, i.e. milk with lower content of fat, but inverse association between high fat diary and overweight (Brouwer-Brolsma et al., 2018). Further studies are suggested by the author of mentioned study.
Oat milk

Amongst cereals, oat has a relatively high fat content. However, when comparing the milks, oat milk comprises the lowest content, see Table 3. Oat has a high content of unsaturated fatty acids (Bryngelsson et al., 2002). The FA composition consists of mainly 18:1, 18:2 followed by 16:0 and smaller amounts of 18:3 and 18:0 (Delcour & Hoseney, 2010). Thus, oat contains the two essential FA 18:2 and 18:3 (Bender, 2006). Studies addressing the effects between the plant based FA and human health could not be found.

Soy milk

The raw material for soy milk, the soy bean does not store starch as their energy source and therefore some of the energy is stored in form of oil. Up to 20 % of the seeds can consist of oil (Hedley, 2000). However, in the finished soy milk, the fat content is only 1.5 %. The FA composition of the soy bean consists of mainly PUFA, including essential FA 18:2 and 18:3 (Rizzo & Baroni, 2018; Vanga & Raghavan, 2018). Studies addressing the effects between the plant based FA and human health could not be found.

4.1.3 Carbohydrates

Bovine milk

Carbohydrates are one of our main source of energy, together with fat and proteins (Woodruff, 2016). Lactose is the major carbohydrate in milk and constitutes of galactose and glucose (Johnson & Conforti, 2003). When consumed, the sugar is hydrolyzed by the enzyme lactase and thereafter absorbed. Lactose intolerance is due to lack or low activity of this enzyme, resulting in gastrointestinal problems (Walstra et al., 2005).

Oat milk

The oat milk has the largest amount of carbohydrates amongst the compared milks. This is a result of starch being the major component in oat, up to 60% of the dry weight (Zhu, 2017). These carbohydrates, mainly in the form of maltose, origin from natural sources and are not added in Oatly’s drink. However, the starch is enzymatic treated and the sugars present in the milk are breakdown products as result from the hydrolysis (Oatly, 2018a).
Soy milk

Soy beans have a lower content of carbohydrates, around 30-40%, when comparing to other legumes. Only 1.5% is starch as the soy bean does not use starch as storage of energy. The carbohydrate content is mainly consisting of sucrose, but also fiber, which cannot be broken down into sugar molecules (Hedley, 2000). The soy milk has a low content of carbohydrates when compared to bovine and oat milk.

4.1.4 Proteins

Proteins are essential macro nutrients crucial for normal development. Proteins have a variety of functions and act as e.g. enzymes, hormones and receptors in the human body product (Abrahamsson et al., 2006). In a nutritional aspect, proteins are a source of amino acids important for humans. The overall protein content is not the only factor contributing to the protein quality of the product (Abrahamsson et al., 2006). Digestibility, bio-availability, and amino acid composition are also important significant factors for protein quality in relation to nutrition (Singhal et al., 2017).

When comparing the different milks, the bovine milk has the highest amount of protein, 3.57% whereas in the soy milk the content is slightly lower, see Table 3. Oat milk has the lowest protein content with 0.35% and is not comparable to bovine milk in this regard.

Protein quality can be assessed by different methods. The protein digestibility-corrected amino acid score (PDCAAS) is a way of measuring the quality of protein in human nutrition (Michaelsen et al., 2009). This system has been used since 1991 (Lee et al., 2016).

Formula 2. Calculation of protein digestibility-corrected amino acid score (PDCAAS); (Schaafsma, 2000)

\[
PDCAAS (%) = \frac{mg \ of \ limiting \ amino \ acid \ in \ 1 \ g \ of \ protein}{(mg \ of \ same \ amino \ acid \ in \ 1 \ g \ of \ reference \ protein) \times \ fecal \ true \ digestibility \ (%) \times 100}
\]  

As seen in formula 2, the PDCAAS takes into account for the first the limiting amino acid compared to a reference pattern of essential amino acids and is also corrected for the true fecal digestibility of the protein (Schaafsma, 2000).

The highest score a protein can achieve is 100%, which means that the prerequisite of all the essential amino acids is fulfilled. A high-quality protein should score above 80%. A score that exceeds 100% are shortened to 100%, though this limits the data
about the proteins. To use scores above 100 % gives a fuller information about the proteins and its ability to compensate for an substandard protein as a part of a varied diet (Michaelsen et al., 2009). Therefore, total scores are presented in Table 4.

<table>
<thead>
<tr>
<th>Protein source</th>
<th>PDCAAS (%)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovine milk</td>
<td>121</td>
<td>Schaafsma (2000)</td>
</tr>
<tr>
<td>Oat</td>
<td>60</td>
<td>Michaelsen et al. (2009)</td>
</tr>
<tr>
<td>Soy</td>
<td>91</td>
<td>Schaafsma (2000)</td>
</tr>
</tbody>
</table>

Bovine milk has the highest PDCAAS as presented in Table 4, the milk includes all the essential amino acid and have a high nutritional value (Singhal et al., 2017). The PDCAAS for soy is lower because of methionine is the limiting essential amino acid in many plant proteins, including soybeans (Friedman, 1996). Also cysteine is limiting amino acid in soybean (Singhal et al., 2017).

Oats have a low est score compared to soy and bovine milk and are not to be considered a high quality protein due to limited essential amino acid lysine (Michaelsen et al., 2009). This alteration in protein content and quality may pose a risk if the plant-based milks, in specific oat milk, are used as a substitute for bovine milk without the consumer being aware of the difference (Makinen et al., 2016). Especially when it comes to young children and infants a predominant substitution without compensating the lack of proteins can pose a serious nutritional risk (Vitoria, 2017; Makinen et al., 2016).

4.1.5 Fortification

Fortification of a product can only be conducted if the legislations allows it. It must be on dictate from the authority, by EU or the government (The Swedish National Food Agency, 2017). In Sweden fortification of organic products has not been al-

owed (KRAV., 2017). Organic plant-based milks differ therefore in nutritional values from the conventional plant-based milks and bovine milk and are not comparable to regarding to nutritional value (Sethi et al., 2016). Oat milk that is not fortified lacks the content of B2, vitamin B12, vitamin D and vitamin A. Concerning calcium it only contains 5 mg/100g which is only 3.1 % of the corresponding content in bovine milk. Soymilk lacks vitamin B12 as well as vitamin D and vitamin A (The Swedish National Food Agency, 2017). However, new legislation in Sweden, starting from the 16th of May 2018 demands a larger group of food stuff to be fortified with vitamin D, plant-based beverages amongst others. Since organic products only
can be fortified if there is a demand on the certain food stuff, this implements that even organic plant-based beverages have to be fortified with vitamin D (The Swedish National Food Agency, 2018a).

4.2 Bioactive compounds

A bioactive compound is an extranutritional food component, often present in small amounts, that impact physiological or cellular activities in our bodies. Thus, it can influence our body function and ultimately be beneficial to our health (Kris-Etherton et al., 2002).

4.2.1 Bovine milk

Milk contains several physiological active peptides (Clare & Swaisgood, 2000). An example is lactoferrins which is an iron-binding protein that originates from the mucosal epithelial cells of many mammals, cows included (González-Chávez et al., 2009; Legrand et al., 2008). The amount of lactoferrin in milk is around 100 µg/ml (Cheng et al., 2008). Lactoferrin have a broad spectrum of bacteriostatic effects (Demmelmair et al., 2017). It has been researched whether lactoferrin can be a part of human cancer treatment, with some promising results (Hill & Newburg, 2015). But further studies are required. Other bioactive compounds present in milk are glycolipids which acts antimicrobial. Isracidin as well as cascocidin are two other types of bio active compounds derived from α-casein which also have antimicrobial effect (Park & Nam, 2015). Another compound, a Proline Rich Polypeptide (PRP) has shown promising results when presented as treatment of Alzheimer’s disease patients. It has been tested in clinical trials where its treatment effects have been proven and its mode of action has also been studied (Artym & Zimecki, 2013).

4.2.2 Oat milk

Oats consists of approximately 3-7% of the soluble dietary fibre β-glucan (Åman et al., 2004). β-glucan can attenuate glycemic responses after meals, help insulin regulation and lower serum cholesterol levels (Ajithkumar et al., 2005). European Food Safety Authority (EFSA) have approved health claims for β-glucans origin from oats (EFSA Panel on Dietetic Products & Allergies, 2011). The functional effects of the β-glucan are due to the viscosity of the fibre in the human intestinal tract (Åman et al., 2004). The viscosity is affected by the β-glucans molecular weight,
amount and solubility. If the health promoting effects of β-glucan should be maintained through processing of oat products, such as oat milk, concentration in the raw material is of importance. It is also central to endorse that the solubility is maintained and that the exposure to enzymatic breakdown of enzyme susceptible β-glucan is kept to a minimum (Anttila et al., 2004). Since enzymatic breakdown is a part of Oatlys production process, the molecular weight of the β-glucan in Oatlys drink would be of interest to know. However, no such data have been found.

4.2.3 Soy milk
Isoflavones, also called phytoestrogens, are a natural occurring phenolic compound in soy (Kang et al., 2010). The structural similarity to the estrogen allows it to bind to estrogen receptor, thus acts as a hormone in the human body (Duncan, 2016). Various studies have been conducted regarding isoflavones and human health. Isoflavones have been reported to have beneficial effect on menopause symptoms, however some contradicting result have been presented in other studies (Duncan, 2016). Furthermore, isoflavones in relation to breast cancer have been studied, both regarding a positive preventative effect but also potential negative effects. A reduction in risk for breast cancer has been reported in a number of studies (Duncan, 2016).
5 Future perspective for plant-based milk

The future for plant-based milks is promising as plant-based alternatives to milk are a growing segment on the market (Sethi et al., 2016).

A milk based on yellow pea protein was launched in Sweden 2018, as an alternative to bovine milk. The milk is produced in Sweden, but on yellow pea protein grown in Europe (Sproud Original Drink – Europas första mjölkalternativ baserat på ärtprotein, 2018).

Legumes poses as a good source of protein and can be a way of fulfill the increasing demand for proteins (Multari et al., 2015). Other legumes than pea showing a future potential is lupin and fava bean. Lupin, which is able to be grown under Swedish conditions, have been used in plant-based yoghurt and also in tempeh (Lupinta, 2019; Axfood, 2017) . Possibly, lupin could be a source to plant-based milk as well.

Fava bean is another legume suitable for Swedish climate and is now in focus in a project by Swedish University of Agricultural Science. The project aims to use plant breeding for improvement of the characteristics of fava beans. Specific quality parameters important for creating desirable foods of fava bean are also to be explored (Grimberg, 2019). This gives a rise to the possibility of using fava bean grown in Sweden, for making plant-based milk.
6 Discussion

Nowadays the research on nutrition does not focus on individual nutrients and food stuff, thus the whole diet and dietary patterns are important. Single food stuff plays an important role but the dietary approaches that are the main factors when looking at health linked to the diet (Ministerråd, 2014). Hence, to solely look at bovine milk, oat milk and soy milk and try to decide which one to choose from a health and nutritional perspective, is difficult. It depends on what the milk are supposed to contribute with in the specific diet of consumers. The plant-based milks are labelled as an alternative to bovine milk. However, it is important to remember that they cannot be compared to bovine milk regarding the nutritional content. Thus, it is not to recommend to use the plant based milks as a substitute for bovine milk without insight in the different nutritional content (Singhal et al., 2017). The nutritional profile of plant-based milks could be improved e.g. by further fortification or alternating the production processes, but the cost and environmental impact would be affected. Nevertheless, plant-based milks can have other values, e.g. to improved specific health issues, like the β-glucan in the oat milk which can help with cholesterol regulation (Ajithkumar et al., 2005).

When comparing bovine milk with plant-based alternatives like oat milk and soy milk in regard of GHG emission, oat milk and soy milk results in lower GHG emissions than bovine milk. Bovine milk also requires larger land areas for production (Makinen et al., 2016). However, the bovine milk production contributes to biodiversity, preservation of cultural landscape and also meet production (Robert Kiefer et al., 2015).

A sustainable diet needs to take many aspects in to consideration, the complexity of many nutrients as well as many environmental factors. When placing GHG emission in contrast to nutritional values, bovine milk preforms better since it is more calorie dense and provides essential nutrients (Smedman et al., 2010).

The bovine milk and the plant-based substitutes are, as this comparison shows, very different in many aspects. Thus, they do not have to be opponents in the same segment, but complements.
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