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**Department of Molecular Sciences**

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

Louise Helsing

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**Supervisor:** Monika Johansson, Swedish University of Agricultural Sciences, Department of Molecular Sciences

**Examiner:** Jana Pickova, Swedish University of Agricultural Sciences, Department of Molecular Sciences

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**Swedish University of Agricultural Sciences**
Faculty of Natural Resources and Agricultural Sciences
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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.

Now a days, 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 växande marknad och används ofta som alternativ till komjölk. Anledningarna till att välja ett växtbaserat alternativ kan vara av medicinsk natur, så som allergi mot mjölkprotein eller laktosintolerans. Livsstilsfaktorer så som en vegetarisk eller en vegansk diet kan vara ytterligare en anledning till valet. Syftet med denna litteraturstudie var att jämföra komjölk med två vanligt förekommande växtbaserade drycker: sojamjölk och havremjölk; samt att undersöka framtida möjligheter för växtbaserad mjölk.

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

Ett ämne som fått stor betydelse i vår tid är klimatförändringarna och till följd av detta har miljöeffekterna av vår kost hamnat i fokus. Komjölk ger upphov till större utsläppet av växthusgaser jämfört med havremjölk men om man jämför utsläppen av växthusgaser med näringsinnehållet i produkterna, så är komjölk att föredra. Flertalet faktorer, så som proteininnehåll och proteinets kvalitet, vitaminer och mineraler, är involverade när man jämför produkternas näringsaspekter. Men man kan dra slutsatsen att de skiljer sig avsevärt i proteininnehåll och proteinets kvalitet. Därför bör växtbaserad mjölk inte användas som ersättning för komjölk utan som ett komplement.



*Nyckelord:* komjölk, växtbaserad dryck, växtbaserad mjölk, miljöpåverkan, näringsinnehåll, jämförelse, produktionsprocess

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# 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 wide spread 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[1]. 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

1. $V_s = (2/9)r^2g\ (p_p-p_f)/\eta$. 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 milks 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 $HCO_3^-$. 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 $CO_2$ equivalents ($CO_2$-eq). $CO_2$-eq emissions for bovine milk, oat milk and soy milk, estimated for their life cycle, are presented in table 1.

Table 1. *Global warming potential, expressed as $CO_2$-equivalents/kg for bovine milk, oat milk and soy milk*

| **Product** | **$CO_2$-eq/kg product** | **References** |
|---|---|---|
| Bovine milk | 0.84-1.30 | de Vries and de Boer (2010) |
| Oat milk | 0.21 | Makinen *et al.* (2016) |
| Soy milk | 0.31 | Makinen *et al.* (2016) |

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)*

$$NDCI\ index\ = \frac{Nutrient\ density\ of\ Y}{CO_2\ eq\ for\ 100\ g\ of\ Y} \qquad (1.)$$

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

| **Product** | **NDCI*** |
|---|---|
| Bovine milk | 0.46 |
| Oat milk | 0.07 |
| Soy milk | 0.25 |

*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 emphases 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 bio diversity and cultural landscapes but also meat production (Robert Kiefer *et al.*, 2015). Ruminants also can utilize grass bio mass 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 *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 forficate their product Havredryck 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)

$B_{12}$, 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)*

| Nutritional information (100 g) | Bovine milk (1.5% fat) | Oat milk | Soy milk |
|---|---|---|---|
| **Energy** (kcal) | 47 | 42 | 37 |
| **Energy** (kJ) | 198 | 174 | 154 |
| **Fat** (g) | 1.5 | 1.1 | 1.5 |
| Saturates (g) | 0.96 | 0.09 | 0.15 |
| Mono-unsaturated (g) | 0.37 | 0.55 | 0.26 |
| Polyunsaturated (g) | 0.04 | 0.32 | 0.61 |
| **Carbohydrates** (g) | 4.9 | 7.1 | 3.2 |
| Sugar total (g) | 4.9 | 3.2 | 2.4 |
| Fibre (g) | 0 | 0.8 | 0 |
| **Proteins** (g) | 3.57 | 0.35 | 2.57 |
| **Salt** (g) | 0.10 | 0.10 | 0.09 |
| **Vitamins** | | | |
| Vitamin D (µg) | 1.00 (20%) * | 1.62 (32.4%) * | 0.74 (14.8%) * |
| Vitamin A (µg) | 13.8 (1.7%) * | 36.3 (4.5%) * | 0.00 (0 %) * |
| Vitamin $B_2$ (mg) | 0.15 (10.7%) * | 0.24 (17.1%) * | 0.21 (15%) * |
| Vitamin $B_{12}$ (µg) | 0.59 (23.6%) * | 0.46 (18.4%) * | 0.38 (15.2%) * |
| **Minerals** | | | |
| Calcium (mg) | 163 (20.4%) * | 120.0 (15%) * | 96.5 (12.1%) * |

* = Daily recommended intake (%) (The Swedish National Food Agency, 2015).

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 $D_2$ and $D_3$, where $D_3$ has the only structure naturally present in food. This is also the form obtained when UV-light converts the intermediate 7-dehydrocholesterol to $D_3$ in the epidermal cells of the skin (Coultate, 2016).

$D_3$ used for enrichment are extracted from the fat of sheep´s wool, thus origins from animal kingdom making it not apposite for vegans. $D_2$ 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 $D_3$. A study conducted by Tripkovic *et al.* (2017) emphatically displays that the efficiency of $D_3$ is more than double compared to $D_2$ 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 $D_3$, 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 gastro intestinal 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 bean 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)*

$$PDCAAS\ (\%) = \frac{mg\ of\ limiting\ amino\ acid\ in\ 1\ g\ of\ protein}{(mg\ of\ same\ amino\ acid\ in\ 1\ g\ of\ reference\ protein \times fecal\ true\ digestibility\ (\%) \times 100)} \quad (2.)$$

As seen in formula 2, the PDCAAS takes in to 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 shorten 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.

*Tabell 4. The protein digestibility-corrected amino acid score (PDCAAS) values for bovine-, oat- and soy milk. The PDCAAS for oat and soy are based on the raw material*

| Protein source | PDCAAS (%) | References |
|---|---|---|
| **Bovine milk** | 121 | Schaafsma (2000) |
| **Oat** | 60 | Michaelsen et al. (2009) |
| **Soy** | 91 | Schaafsma (2000) |

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 lowest 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 allowed (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 $B_2$, vitamin $B_{12}$, 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 $B_{12}$ as well as vitamin D and vitamin A (The Swedish National Food Agency, 2017). However, new legislation in Sweden, starting from the $16^{th}$ 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 extranutrional 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 origins 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 bio diversity, 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.

# References


EUROPAPARLAMENTETS OCH RÅDETS FÖRORDNING (EU) nr 1308/2013
av den 17 december 2013
om upprättande av en samlad marknadsordning för jordbruksprodukter och om upphävande av rådets förordningar (EEG) nr 922/72, (EEG) nr 234/79, (EG) nr 1037/2001 och (EG) nr 1234/2007 (2013).

Abrahamsson, L., Andersson, A., Becker, W., Nilsson, G. & Aunver, K. (2006). *Näringslära för högskolan*. 5., [rev.] uppl. ed. Stockholm: Stockholm : Liber.

AHDB (2016). Diary statistics: An insider´s guide 2016. Available from: https://dairy.ahdb.org.uk/resources-library/market-information/dairy-statistics/dairy-statistics-an-insiders-guide-2016/#.WsSURIhuY2x [2018-04-04].

Ajithkumar, A., Andersson, R. & Åman, P. (2005). Content and Molecular Weight of Extractable β-Glucan in American and Swedish Oat Samples. *Journal of Agricultural and Food Chemistry,* 53(4), pp. 1205-1209.

Alpro. *Alpro Soja Original*. Available at: https://www.alpro.com/se/produkter/drycker/soja-naturell/original [2018-04-11].

Anttila, H., Sontag-Strohm, T. & Salovaara, H. (2004). Viscosity of beta-glucan in oat products. *Agricultural and Food Science,* 13(1-2), pp. 80-87.

Artym, J. & Zimecki, M. (2013). Milk-derived proteins and peptides in clinical trials. *Postepy Hig Med Dosw (Online),* 67, pp. 800-16.

Axfood *Har du smakat Lupinghurt?* Available at: http://www.axfood.se/media-och-opinion/hallbarhetschefens-blogg/2017/har-du-smakat-lupinghurt2/

https://www.axfood.se/media-och-opinion/hallbarhetschefens-blogg/2017/har-du-smakat-lupinghurt2/.

Bender, D.A. (2006). Dictionary. In: Bender, D.A. (ed. *Benders' Dictionary of Nutrition and Food Technology (Eighth Edition)* Woodhead Publishing, pp. 1-521. Available from: http://www.sciencedirect.com/science/article/pii/B9781845690519500016.

Brouwer-Brolsma, E.M., Sluik, D., Singh-Povel, C.M. & Feskens, E.J.M. (2018). Dairy shows different associations with abdominal and BMI-defined overweight: Cross-sectional analyses exploring a variety of dairy products. *Nutr Metab Cardiovasc Dis,* 28(5), pp. 451-460.

Bryngelsson, S., Mannerstedt-Fogelfors, B., Kamal-Eldin, A., Andersson, R. & Dimberg, L.H. (2002). Lipids and antioxidants in groats and hulls of Swedish oats (Avena sativa L). *Journal of the Science of Food and Agriculture,* 82(6), pp. 606-614.

Burney, J.A., Davis, S.J. & Lobell, D.B. (2010). Greenhouse gas mitigation by agricultural intensification. *Proc Natl Acad Sci U S A,* 107(26), pp. 12052-7.

Cheng, J.B., Wang, J.Q., Bu, D.P., Liu, G.L., Zhang, C.G., Wei, H.Y., Zhou, L.Y. & Wang, J.Z. (2008). Factors affecting the lactoferrin concentration in bovine milk. *J Dairy Sci,* 91(3), pp. 970-6.

Cheremisinoff, N.P. (2016). *Pollution Control Handbook for Oil and Gas Engineering*. Hoboken, UNITED STATES: John Wiley & Sons, Incorporated. Available from: http://ebookcentral.proquest.com/lib/slub-ebooks/detail.action?docID=4510843.

Clare, D.A. & Swaisgood, H.E. (2000). Bioactive Milk Peptides: A Prospectus1. *Journal of Dairy Science,* 83(6), pp. 1187-1195.

Coultate, T.P. (2016). *Food : the chemistry of its components*. 6. ed. ed: Cambridge : Royal Society of Chemistry.

Dahllöv, O. & Gustafsson, M. (2008). Livscykelanalys av Oatly havredryck.

de Vries, M. & de Boer, I.J.M. (2010). Comparing environmental impacts for livestock products: A review of life cycle assessments. *Livestock Science,* 128(1), pp. 1-11.

Delcour, J. & Hoseney, R. (2010). *Principles of Cereal Science and Technology*.

Demmelmair, H., Prell, C., Timby, N. & Lönnerdal, B. (2017). Benefits of Lactoferrin, Osteopontin and Milk Fat Globule Membranes for Infants. *Nutrients,* 9(8), p. 817.

Deswal, A., Deora, N.S. & Mishra, H.N. (2014). Optimization of Enzymatic Production Process of Oat Milk Using Response Surface Methodology. *Food and Bioprocess Technology,* 7(2), pp. 610-618.

Duncan, A.M. (2016). Soy Beans: Dietary Importance. In: Caballero, B., Finglas, P.M. & Toldrá, F. (eds) *Encyclopedia of Food and Health*. Oxford: Academic Press, pp. 43-47. Available from: http://www.sciencedirect.com/science/article/pii/B9780123849472006395.

EFSA Panel on Dietetic Products, N. & Allergies (2011). Scientific Opinion on the substantiation of health claims related to beta-glucans from oats and barley and maintenance of normal blood LDL-cholesterol concentrations (ID 1236, 1299), increase in satiety leading to a reduction in energy intake (ID 851, 852), reduction of post-prandial glycaemic responses (ID 821, 824), and "digestive function" (ID 850) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal,* 9(6), p. 2207.

Eidstedt, M. (2017). *Livsmedelskonsumtion och näringsinnehåll. Uppgifter till och med 2016.* Jordbruksverket.se: Helen Stoye, SCB.

FAO. *About Codex Alimentarus*[2018-04-11].

Foods, A. *Mjölk med lång hållbarhet*[22/10-2019].

Friedman, M. (1996). Nutritional Value of Proteins from Different Food Sources. A Review. *Journal of Agricultural and Food Chemistry,* 44(1), pp. 6-29.

Fujimaki, M., Arai, S., Kirigaya, N. & Sakurai, Y. (1965). Studies on Flavor Components in Soybean. *Agricultural and Biological Chemistry,* 29(9), pp. 855-863.

Gedam, K., Prasad, R. & Vijay, V.K. (2007). The study on UHT processing of milk: A versatile option for rural sector. *World J. Dairy Food Sci,* 2(2), pp. 49-53.

Giri, S.K. & Mangaraj, S. (2012). Processing Influences on Composition and Quality Attributes of Soymilk and its Powder. *Food Engineering Reviews,* 4(3), pp. 149-164.

González-Chávez, S.A., Arévalo-Gallegos, S. & Rascón-Cruz, Q. (2009). Lactoferrin: structure, function and applications. *International Journal of Antimicrobial Agents,* 33(4), pp. 301.e1-301.e8.

Gray, C.L., Goddard, E., Karabus, S., Kriel, M., Lang, A.C., Manjra, A.I., Risenga, S.M., Terblanche, A.J., van der Spuy, D.A. & Levin, M.E. (2015). Epidemiology of IgE-mediated food allergy. *SAMJ: South African Medical Journal,* 105, pp. 68-69.

Grimberg, Å. (2019). Framtidens åkerböna för mat och foder. *SLU.SE*.
Hedley, C.L. (2000). *Carbohydrates in Grain Legume Seeds : Improving Nutritional Quality and Agronomic Characteristics*. Wallingford, UNITED KINGDOM: CABI. Available from: http://ebookcentral.proquest.com/lib/slub-ebooks/detail.action?docID=293847.
Hill, D.R. & Newburg, D.S. (2015). Clinical applications of bioactive milk components. *Nutrition reviews,* 73(7), pp. 463-476.
Hochwallner, H., Schulmeister, U., Swoboda, I., Spitzauer, S. & Valenta, R. (2014). Cow's milk allergy: From allergens to new forms of diagnosis, therapy and prevention(). *Methods (San Diego, Calif.),* 66(1), pp. 22-33.
Johnson, J.M. & Conforti, F.D. (2003). LACTOSE A2 - Caballero, Benjamin. In: *Encyclopedia of Food Sciences and Nutrition (Second Edition)*. Oxford: Academic Press, pp. 3472-3476. Available from: https://www.sciencedirect.com/science/article/pii/B012227055X00674X.
Kang, J., Badger, T.M., Ronis, M.J.J. & Wu, X. (2010). Non-isoflavone Phytochemicals in Soy and Their Health Effects. *Journal of Agricultural and Food Chemistry,* 58(14), pp. 8119-8133.
Kratz, M., Baars, T. & Guyenet, S. (2013). The relationship between high-fat dairy consumption and obesity, cardiovascular, and metabolic disease. *European Journal of Nutrition,* 52(1), pp. 1-24.
KRAV. *Tillsatser tillåtna i KRAV-märkt produktion*. Available at: http://www.krav.se/sites/default/files/tillsatser_tillatna_i_krav-markt_produktion.pdf.
Kris-Etherton, P.M., Hecker, K.D., Bonanome, A., Coval, S.M., Binkoski, A.E., Hilpert, K.F., Griel, A.E. & Etherton, T.D. (2002). Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer. *Am J Med,* 113 Suppl 9B, pp. 71s-88s.
Kutz, M. (2013). *Handbook of Farm, Dairy and Food Machinery Engineering (2nd Edition)*: Elsevier. Available from: https://app.knovel.com/hotlink/toc/id:kpHFDFMEE4/handbook-farm-dairy-food/handbook-farm-dairy-food.
Lee, W.T., Weisell, R., Albert, J., Tome, D., Kurpad, A.V. & Uauy, R. (2016). Research Approaches and Methods for Evaluating the Protein Quality of Human Foods Proposed by an FAO Expert Working Group in 2014. *J Nutr,* 146(5), pp. 929-32.
Legrand, D., Pierce, A., Elass, E., Carpentier, M., Mariller, C. & Mazurier, J. (2008). Lactoferrin structure and functions. *Adv Exp Med Biol,* 606, pp. 163-94.
Liu, K. (2008). 14 - Food Use of Whole Soybeans. In: *Soybeans* AOCS Press, pp. 441-481. Available from: https://www.sciencedirect.com/science/article/pii/B9781893997646500172.
Lupinta *Lupinta*. Available at: https://lupinta.se/.
Makinen, O.E., Wanhalinna, V., Zannini, E. & Arendt, E.K. (2016). Foods for Special Dietary Needs: Non-dairy Plant-based Milk Substitutes and Fermented Dairy-type Products. *Crit Rev Food Sci Nutr,* 56(3), pp. 339-49.
McMichael, A.J., Powles, J.W., Butler, C.D. & Uauy, R. (2007). Food, livestock production, energy, climate change, and health. *The Lancet,* 370(9594), pp. 1253-1263.
*Mellanmjölk 1,5%*. Available at: https://www.dabas.com/ProductSheet/Details.ashx/10772.
Michaelsen, K.F., Hoppe, C., Roos, N., Kaestel, P., Stougaard, M., Lauritzen, L., Molgaard, C., Girma, T. & Friis, H. (2009). Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. *Food Nutr Bull,* 30(3 Suppl), pp. S343-404.
Ministerråd, N. (2014). *Nordic Nutrition Recommendation 2012 : Integrating nutrition and physical activity*).
Multari, S., Stewart, D. & Russell, W.R. (2015). Potential of Fava Bean as Future Protein Supply to Partially Replace Meat Intake in the Human Diet. *Comprehensive Reviews in Food Science and Food Safety,* 14(5), pp. 511-522.
Murphy, P.A. (2008). 8 - Soybean Proteins. In: *Soybeans* AOCS Press, pp. 229-267. Available from: https://www.sciencedirect.com/science/article/pii/B9781893997646500111.

Nylander, A., Jonsson, L., Marklinder, I. & Nydahl, M. (2014). *Livsmedelsvetenskap*. 2., [rev. och uppdaterade] uppl. ed. Lund: Lund : Studentlitteratur.
*Oatly Havredryck*. Available at: https://www.dabas.com/ProductSheet/Details.ashx/182479.
Oatly. *Havredryck*. Available at: http://www.oatly.com/products/sweden/havredryck/ [2018-04-11].
Oatly. *Vår process*. Available at: http://www.oatly.com/process/ [2018-03-29 16:34:28].
Oxford (2018). milk | Definition of milk in English by Oxford Dictionaries. In: Press, O.U. (ed. *Oxford Dictionaries | English.*
Park, Y.W. & Nam, M.S. (2015). Bioactive Peptides in Milk and Dairy Products: A Review. *Korean journal for food science of animal resources,* 35(6), pp. 831-840.
Rizzo, G. & Baroni, L. (2018). Soy, Soy Foods and Their Role in Vegetarian Diets. *Nutrients,* 10(1), p. 43.
Robert Kiefer, L., Menzel, F. & Bahrs, E. (2015). Integration of ecosystem services into the carbon footprint of milk of South German dairy farms. *Journal of Environmental Management,* 152, pp. 11-18.
Röös, E., Patel, M. & Spångberg, J. (2016). Producing oat drink or cow's milk on a Swedish farm — Environmental impacts considering the service of grazing, the opportunity cost of land and the demand for beef and protein. *Agricultural Systems,* 142, pp. 23-32.
Schaafsma, G. (2000). The Protein Digestibility–Corrected Amino Acid Score. *J Nutr,* 130(7), pp. 1865S-1867S.
Sebastiani, G., Herranz Barbero, A., Borras-Novell, C., Alsina Casanova, M., Aldecoa-Bilbao, V., Andreu-Fernandez, V., Pascual Tutusaus, M., Ferrero Martinez, S., Gomez Roig, M.D. & Garcia-Algar, O. (2019). The Effects of Vegetarian and Vegan Diet during Pregnancy on the Health of Mothers and Offspring. *Nutrients,* 11(3).
Sethi, S., Tyagi, S.K. & Anurag, R.K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. *Journal of Food Science and Technology,* 53(9), pp. 3408-3423.
Singhal, S., Baker, R.D. & Baker, S.S. (2017). A Comparison of the Nutritional Value of Cow's Milk and Nondairy Beverages. *Journal of Pediatric Gastroenterology and Nutrition,* 64(5), pp. 799-805.
Smedman, A., Lindmark-Månsson, H., Drewnowski, A. & Edman, A.-K.M. (2010). Nutrient density of beverages in relation to climate impact. *Food & nutrition research,* 54(1), p. 5170.
*Sojadryck original Alpro*. Available at: https://www.dabas.com/ProductSheet/Details.ashx/121364.
Sonck, M. (2017). Svenskarna köper allt mer vegitabilisk mjölk. Available from: https://www.svt.se/nyheter/inrikes/svenskarna-koper-allt-mer-vegetabilisk-mjolk
*Sproud Original Drink – Europas första mjölkalternativ baserat på ärtprotein*. Available at: http://www.mynewsdesk.com/wemake/pressreleases/sproud-original-drink-europas-foersta-mjoelkalternativ-baserat-paa-aertprotein-2697338.
The Swedish National Food Agency, S. *Näringsvärde*. Available at: https://www.livsmedelsverket.se/livsmedel-och-innehall/text-pa-forpackning-markning/naringsvarde [2018-04-11].
The Swedish National Food Agency, S. (2017-05-30). *Berikning*. Available at: https://www.livsmedelsverket.se/produktion-handel--kontroll/produktion-av-livsmedel/berikning#Produkter%20som%20inte%20f%C3%A5r%20berikas [2018-04-14].
The Swedish National Food Agency, S. *Nu blir det lättare att få i sig D-vitamin - fler livsmedel berikas*. Available at: https://www.livsmedelsverket.se/om-oss/press/nyheter/pressmeddelanden/nu-blir-det-lattare-att-fa-i-sig-d-vitamin-fler-livsmedel-berikas.

The Swedish National Food Agency, S. *Vitamin D*. Available at: https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/vitaminer-och-antioxidanter/vitamin-d.

Tripkovic, L., Wilson, L.R. & Lanham-New, S.A. (2017). Vitamin D2 vs. vitamin D3: They are not one and the same. *Nutrition Bulletin,* 42(4), pp. 331-337.

Walstra, P., Wouters, J.T.M., Geurts, T.J. & Geurts, T.J. (2005). *Dairy Science and Technology*. Baton Rouge, UNITED STATES: CRC Press LLC. Available from: http://ebookcentral.proquest.com/lib/slub-ebooks/detail.action?docID=263085.

Van Winckel, M., Vande Velde, S., De Bruyne, R. & Van Biervliet, S. (2011). Clinical practice. *European Journal of Pediatrics,* 170(12), pp. 1489-1494.

Vanga, S.K. & Raghavan, V. (2018). How well do plant based alternatives fare nutritionally compared to cow's milk? *Journal of Food Science and Technology,* 55(1), pp. 10-20.

Vitoria, I. (2017). The nutritional limitations of plant-based beverages in infancy and childhood. *Nutr Hosp,* 34(5), pp. 1205-1214.

Woodruff, K. (2016). *Sports Nutrition*. New York, UNITED STATES: Momentum Press. Available from: http://ebookcentral.proquest.com/lib/slub-ebooks/detail.action?docID=4398510.

Vuorisalo, T., Arjamaa, O., Vasemagi, A., Taavitsainen, J.P., Tourunen, A. & Saloniemi, I. (2012). High lactose tolerance in North Europeans: a result of migration, not in situ milk consumption. *Perspect Biol Med,* 55(2), pp. 163-74.

Zhu, F. (2017). Structures, properties, modifications, and uses of oat starch. *Food Chemistry,* 229, pp. 329-340.

Åman, P., Rimsten, L. & Andersson, R. (2004). Molecular weight distribution of β-glucan in oat-based foods. *Cereal Chemistry,* 81(3), pp. 356-360.