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– Focus on composition and properties

Variationer i svensk mjölk från 1995 till 2020 - fokus på sammansättning och egenskaper

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Swedish University of Agricultural Sciences, SLU
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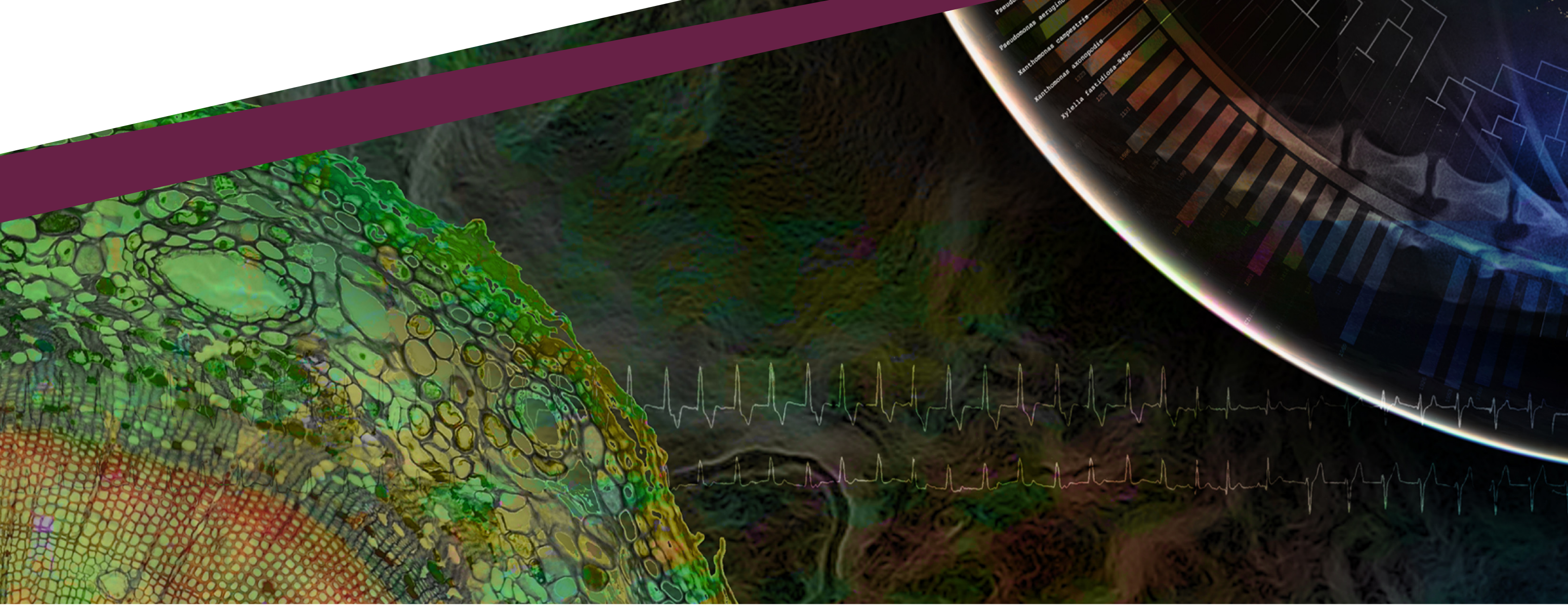

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Abstract

The composition and properties of Swedish bovine raw milk are influenced by several factors which have varied over the last 25 years. Factors influencing milk quality include: bovine breed, stage of lactation, type of feed, and climate. The overall aim of this thesis was to investigate the variation of Swedish bovine raw milk quality over the last 25 years. Changes on Swedish dairy farms and dairies were also investigated. This thesis is a literature review. Searches in online databases were conducted for primary research. Scientific studies, book chapters, Swedish databases, websites, and personal communications were also used to collect information. The literature review revealed that over the last 25 years the protein content has increased from 3.34% to 3.50% while the fat content has been stable around 4.2%. Over time, variations in lactose, calcium, citric acid, somatic cell count, and pH were small. Sweden has gone from several small dairy farms to fewer farms with larger herd size.

Keywords: Protein, Fat, Lactose, Calcium, Citrate, Somatic cell count, pH

Sammanfattning

Den svenska obehandlade mjölkens kvalité påverkas av flera olika faktorer och har varierat de senaste årtiondena. Faktorer som påverkar mjölkens kvalité är exempelvis ras, laktationsstadie, foder samt klimatförhållanden. Det övergripande syftet med uppsatsen var att ta reda på vilka variationer som har skett i den svenska mjölkråvaran de senaste årtiondena. Förändringar på svenska mjölkgårdar och mejerier studerades också. Denna uppsats är en litteraturstudie. Internationella databaser, svenska databaser, vetenskapliga artiklar, böcker och webbsidor användes samt en intervju genomfördes för att söka och samla information. Protein och fetthalten visade sig ha signifikanta variationer i mjölken både mellan säsong och årtionden. Proteinhalten ökade från 3.34% till 3.50% medan fetthalten har varit stabil på 4.2%. Över tid har mjölkens innehåll av laktos, kalcium, citronsyra, somatiska celler och pH-värdet endast visat på mindre variationer. Sverige har gått från att ha många små mjölkgårdar till färre antal gårdar med större besättningar.

Nyckelord: Protein, Fett, Laktos, Kalcium, Citronsyra, Somatiska celler, pH

Preface

If You Ate Today, Thank a Farmer

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Abbreviations

Ca^{2+}	Calcium ions
$CaCl_2$	Calcium chloride
Fig.	Figure
EU	European Union
NAV	Nordic Cattle Genetic Evaluation
NC	Non-coagulating
RCT	Rennet coagulation time
SKB	Swedish Mountain Cattle and Swedish Red Polled Cattle
SLB	Swedish Friesian cattle
SRB	Swedish Red and White Cattle
SLU	Swedish University of Agricultural Sciences
SCC	Somatic cell count
SMHI	The Swedish Meteorological and Hydrological Institute
SVA	National Veterinary Institute of Sweden
UHT	Ultra-high-temperature

1. Introduction

Milk is consumed on all continents over the world and is an essential nutrient source for all mammals (Oftedal 2012). Ruminants are unique mammals. Especially dairy cows are fascinating since they have the ability to digest grass and convert it to milk and meat (Huntington 1997).

Milk consists of five main components: water, protein, fat, lactose, vitamins, and minerals (Foroutan *et al.* 2019). Several factors influence the milk quality, and the composition and properties in the milk are not constant. Factors that influence milk quality include: bovine breed, stage of lactation, type of feed, climate, and farm management (Looper 2012; Fox *et al.* 2015).

Lindmark-Månsson has compiled a couple of larger work with raw data of Swedish bovine raw milk, one in 2001 and the other in 2009. This thesis was performed to give an update of the quality of Swedish bovine raw milk and see how the quality has varied over years and seasons. Updated raw data of milk quality is important to understand how factors like: breeding, milking routines, animal welfare, seasonality, and payment have affected the quality, but also to be able to produce high quality dairy products and predict future trends.

1.1. Aim/objective

The overall aim of this thesis was to investigate the variation of Swedish raw milk quality (i.e. composition and properties) over the last 25 years. Specific aims were:

► To deepen the understanding on variation of Swedish milk composition and properties over years, based on available data and statistics

► To explain how variations in composition and properties relate to changes at Swedish dairy farms

2. Method

A systematic search of online databases (PubMed, Web of Sciences, and Google Scholar) was conducted for primary research studies and secondary information sources which examine the variation of Swedish milk quality over the years. Scientific studies, book chapters, Swedish databases (Jordbruksverkets statistikdatabas), websites, and personal communications were used to collect information. Sources published before 1965 have not been used in this thesis. Following search combinations and words were used to find sources; Increased + protein + Swedish bovine, Protein content + bovine + season, Somatic + cell + count + bovine + Sweden, fat, lactose, calcium, citrate, pH, and milk. Summary of data were compiled, and qualitative analyses were made in completion of the thesis.

3. Result

3.1. Milk composition

Milk is consumed globally and is an important food source for all mammals (Oftedal 2012). Milk is an emulsion of fat droplets in a water solution (Aynié *et al.* 1992; Gaucher *et al.* 2008) and contains 18 of 22 essential nutrients that humans need. In an average dairy herd, the milk composition is composed by 87% water, 5% lactose, 4% fat, and 3% protein. Vitamins and minerals are present with less than 0.05 % (Diederen *et al.* 2019).

The milk composition is not constant and varies due to several factors (Heck *et al.* 2009). For example, different breeds, feed composition, stage of lactation, number of lactations, age of the cow, diseases, seasonality, and climate (Looper 2012; Fox *et al.* 2015). Fat and protein contents are the two components that varies most in milk, since both components are dependent on the feed. Lactose, vitamins, and minerals are less dependent on the feed and therefore vary to a less extent than the fat and protein contents (Looper 2012).

3.2. Protein

The Swedish Jersey cow has the highest average protein content in milk compared to other Swedish dairy breeds. However, it is also the breed that has the lowest total milk yield (Växa Sverige 2020).

The protein content is higher in the beginning of the lactation, drops during the mid-lactation and increases again towards the end of lactation (Ng-Kwai-Hang *et al.* 1982). The reason to a high protein level in the early lactation is that the milk contains more immunoglobulins which are essential for the new born calf (DeLaval 2002).

It is also possible to regulate the protein content in the milk by adjusting the protein content of the feed (LRF Mjölk 2018). The variation depends of the total amount of energy intake, the forage:concentrate ratio and type of silage and grains (e.g. oats vs. barley) that the cows have been fed (Vanhatalo *et al.* 2006).

The variation of average protein content in Swedish raw milk over the last decades is shown in Fig.1, which shows a steady increase of the average protein content over time. Table 1-A shows that the average protein content has increased from 3.28% in 2000 to 3.50% in 2019. One possible reason for the increase of the average protein content is the increased protein content of the feed given to dairy cows (Karlsson *et al.* 2017). Another reason for the increase of protein is breeding goals. According to Nordic Cattle Genetic Evaluation (NAV), breeding for a higher protein content in milk has been and still is economically beneficial (Fogh *et al.* 2018).

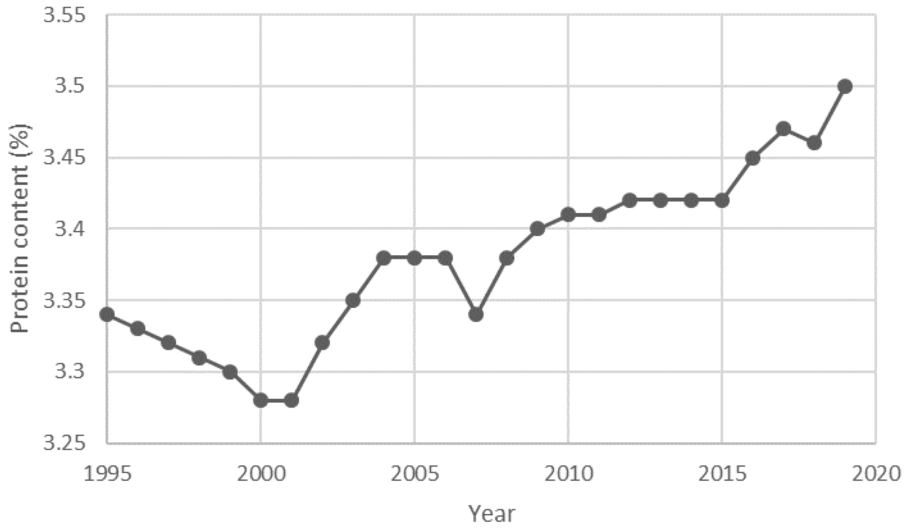

Figure 1. The average protein content in Swedish raw milk from 1995 to 2019 (Jordbruksverkets statistikdatabas 2020d).

During an interview conducted on 16th of April 2020 with dairy farmer Brit – Lis Levin, she agreed with Karlsson *et al.* (2017) that the most likely reason why the protein content has increased is because of the changes in composition of the feed. It is more common nowadays, than 15 years ago, to grow and feed the cows with legumes, like beans and peas, says Levin. Levin, among several of other farmers, feed their cows with a mixture of oats and pea silage.

3.2.1. Seasonal variation

The research by Karlsson *et al.* (2017), found milk protein content seasonally fluctuated, where indoor period was correlated to higher protein content (3.57%) compared to the outdoor period (3.47%). These results are in line with Fig. 2 (Jordbruksverket Statistic Database 2020b). Fig. 2 shows that the protein content is higher during the Swedish autumn and winter periods, especially in October and November.

Other studies found similar results. The New Zealand dairy cows also had the highest protein content during the New Zealand autumn and winter period, April and May, respectively (Li *et al.* 2019). Li *et al.* (2019) also mentioned that one of the main reasons for variation in protein content for European cows is the changes in composition of feed (Li *et al.* 2019).

The outdoor period for Swedish cattle differs depending on the classification of the dairy farm, conventional or organic, and where the dairy farm is geographically located. A conventional Swedish dairy cow must be outside for a minimum of 6 hours per day during the outdoor period. Meanwhile an organic dairy cow must be outside for the majority of the day (minimum 12,5 hours) (Äng *et al.* 2010; Jordbruksverket 2019). The outdoor period for a Swedish dairy cow in the South[1] and Middle[2] of Sweden is between the 1st of April to 31st of October and the cow must be outside for a minimum of 120 and 90 days, respectively. Meanwhile, the outdoor period for a cow in the Northern[3] part of Sweden is between 1st of May to 31st of October and she must be outside for a minimum of 60 days.

When the cattle have their indoor period, silage is given to them as feed. The silage that is given in October and November is taken from the first harvest. Silage from the first harvest has a higher protein value compared to the silage given later during the indoor period. This is a likely explanation to why the protein content is higher in October and November compared to the rest of the year (Levin 2020).

What also stands out in Fig. 2 is the decrease in protein content during the summer of 2018. That year, the drought hit Sweden (Swedish Meteorological and Hydrological Institute 2018) and the whole of Europe. A lot of farmers suffered, both financially and not being able to provide enough high quality feed for their animals (Sjökvist *et al.* 2019).

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[1] Blekinge, Skåne and Halland county

[2] Stockholm, Uppsala, Södermanland, Östergötland, Jönköping, Kronoberg, Kalmar, Gotland, Västra Götaland, Värmland, Örebro and Västmanland county

[3] Dalarna, Gävleborg, Västernorrland, Jämtland, Västerbotten and Norrbotten county

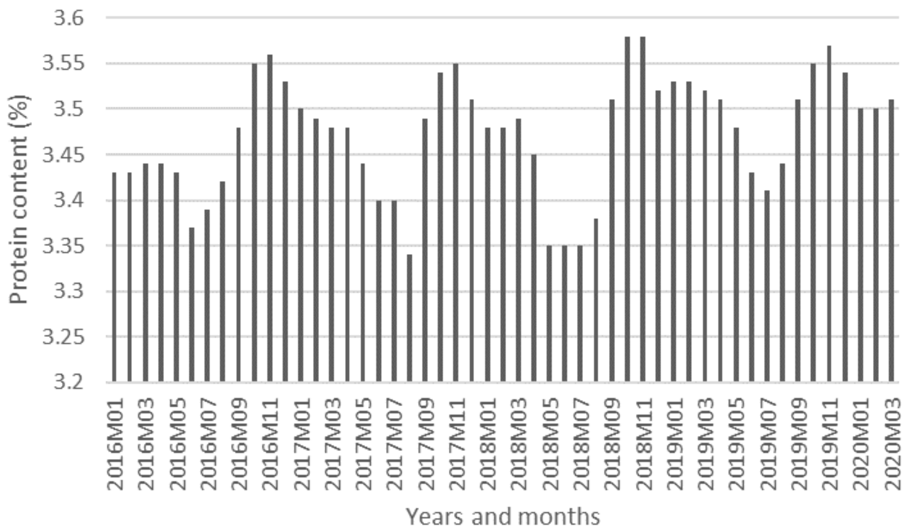

Figure 2. Seasonal variation in protein content for each month from January 2016 (2016M01) to March 2020 (2020M03) (Jordbruksverkets statistikdatabas 2020b).

3.3. Fat

Dairy cattle are ruminants which means that they have the ability to break down cellulose and convert it to sugars and fats (Huntington 1997). They are usually fed a larger amount of roughage and less concentrate. In Sweden, the fat content has decreased significantly from 1995 to 2000 but has been quite stable since the millennium until today (Fig. 3). An explanation to the decrease in fat content between 1995 to 2000 is that Sweden joined the European Union (EU) 1st of January 1995 (Regeringskansliet 2014). As a member in the EU, milk quota was implemented. It was then more advantageously to deliver a larger quantity of milk with a lower fat content than deliver a smaller quantity with a higher fat content (Andersson 2020).

3.3.1. Feed

It is important to note, that cattle feed cannot be replaced with too much concentrate and starch. When more concentrate (including starch) and less fibre are introduced to the feed ration, the fat synthesis in the mammary gland will get affected and, in the end, produce less fat (Palmquist *et al.* 1993). Too much concentrate may cause disorder in the metabolism of rumen which could lead to fat depression (DeLaval 2002). When milk fat depression occurs, depending on the feed, however, the concentration of short-chain fatty acids will decrease meanwhile fatty acids with 18 carbon atoms (C_{18}) will increase (Palmquist *et al.* 1993). Whereas, if more fat is required in the milk, an increased amount of fibre in the feed is recommended (Phelan *et al.* 1982).

Swedish Jersey cows have the highest fat content meanwhile Swedish Friesian cattle (SLB) have the lowest fat content. On the other hand, Jersey cows has a low milk yield with an average of 7 144 kg per cow in 2019. In comparison, SLB had an average yield of 10 551 kg per cow in 2019 (Växa Sverige 2020). Which can explain why the fat content is lower in milk from SLB compared to Jersey.

3.3.2. Stage of lactation

The fat content varies during the lactation. In the early lactation, the fat content is approximately 3.8%. After three months, the cow is in her mid-lactation and has reached the lowest fat content, approximately 3.6%. Towards the end of the lactation, the late lactation, the cow has reached the highest fat content level, of nearly 4.2% (Andersson 2020). The New Zealand dairy cows followed the same fat content curve as the Swedish dairy cows do. Following fat content values were reported from the season 2017 to 2018; early lactation (4.74%), mid lactation (4.90%) and late lactation (5.55%), respectively (Li *et al.* 2019). In New Zealand, seasonal calving is prominent, compared to Sweden, where all year calving is practiced. Therefore, Li *et al.* (2019) concluded that the stage of lactation largely controls the seasonal variations in the composition and psychochemical properties of milk in seasonal calving system.

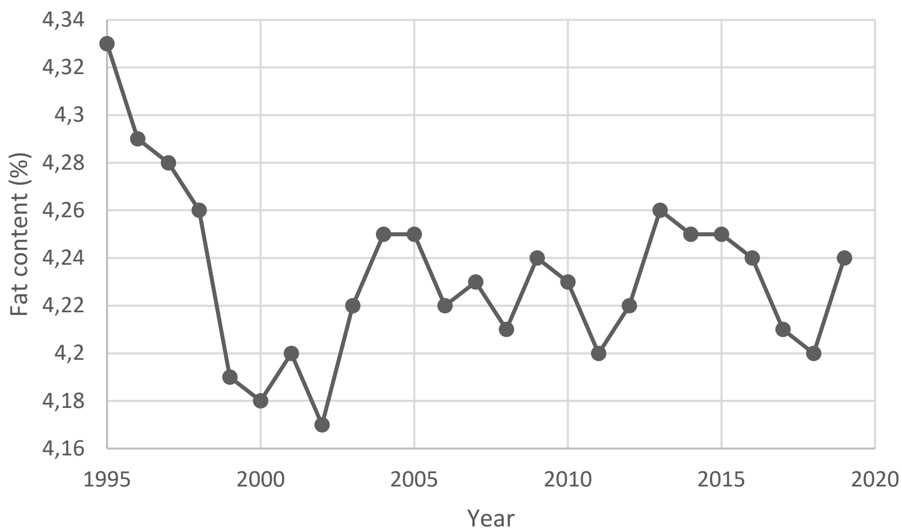

Figure 3. The average fat content in Swedish raw milk from 1995 to 2019 (Jordbruksverkets statistikdatabas 2020c)

3.3.3. Seasonal variation

Even though the average fat content in Swedish raw milk has been stable around 4.22% fat in the last 20 years, does not mean that it stays stable within the year. The fat content of milk varies with seasons. This can be clearly seen in Fig. 4, which shows that the fat content is lower during the summer months, June and July, and highest during autumn, October and November.

What stands out in Fig. 4 is the summer of 2018 when the fat content measured only 4.03% in July, which is the third lowest average fat content value measured since 1995. Table 5-A shows the average fat content in July and August from 1995 to 2019. In 2002, the average fat content measured 3.99% and 3.95%, in July and August, respectively. In contrast, the highest average value was measured 4.41% in May 1995 (Table 5-A).

According to the Swedish Meteorological and Hydrological Institute (SMHI), a heat wave hit Sweden in 2002 (Swedish Meteorological and Hydrological Institute *et al.* 2011). In a research made by the Swedish University of Agricultural Science (SLU), together with the National Veterinary Institute of Sweden (SVA), Lundström *et al.* (2009) explained that long term heat makes cows stressed and the stress influencing the milk production negatively. When a heat wave occurs, cows drink more water, eat less feed, and produce a lower milk yield (Carlsson-Kanyama *et al.* 2010; Jordbruksverket 2017). Heat stress has also shown to decrease the fat content of milk (Summer *et al.* 2019). The heat stress could be one explanation to why the fat content measured extremely low levels in 2002 and 2018 (Table 5-A).

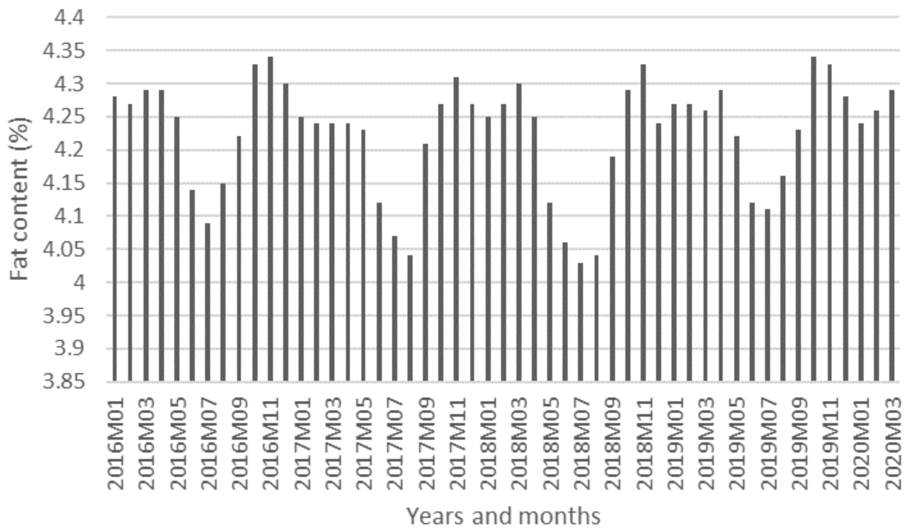

Figure 4. Seasonal variation in fat content for each month from January 2016 (2016M01) to March 2020 (2020M03) (Jordbruksverkets statistikdatabas 2020a)

3.4. Lactose

Lactose, also known as milk sugar, has its highest level in the early lactation and decreases towards the end of the lactation (Phelan *et al.* 1982; Sjaastad *et al.* 2019). This happens due to the degeneration of the mammary gland in the end of lactation. The lactose synthesis is suppressed since it has to adjust for the increased osmotic pressure, caused by the influx of blood constituents (Li *et al.* 2019).

Heck *et al.* (2019) studied the seasonal variation in Dutch bovine raw milk composition and stated that lactose is the component, which stays most stable during the season. This seasonal variation have been emphasized in other studies as well (Lindmark-Månsson *et al.* 2003).

Lindmark-Månsson (2004) investigated the lactose content in Swedish milk and concluded that the lactose content had slightly increased from 4.80% in 1996 to 4.82% in 2001 (Table 2-A). Further studies were performed in 2009 and the lactose content had decreased to 4.73% (Lindmark-Månsson 2012).

Karlsson *et al.* (2017) reported a lactose content of 4.72% in 2015. Lindmark-Månsson (2004, 2012) tested milk samples from different regions in Sweden, meanwhile Karlsson *et al.* (2017) only tested milk samples from dairy cows in northern Sweden. Therefore, the lactose values might not give an exact nationwide indication of how the lactose content changed in Sweden during these years.

Seasonal variation of lactose has been observed in some years in Swedish raw milk (e.g. 1996) whereas, seasonality is absent in some years (e.g. 2001 and 2009). However, geographical variation of lactose content has not been reported (Lindmark-Månsson 2004; Lindmark-Månsson 2012).

3.5. Calcium

Calcium is a very important element for the human body. It gives strengths to teeth and bones and makes it possible for the blood to coagulate (Denholm *et al.* 2019; The Swedish Food Agency 2019). Dairy products are a good source to cover the daily need of calcium (Mekmene & Gaucheron 2011).

Since 1995, the calcium content in Swedish milk has been measured in 1996, 2001, and 2009 (Lindmark-Månsson 2004). Lindmark-Månsson (2004) stated that there was no significant difference in the calcium content in Swedish milk between 1996 and 2001 (114 vs. 113 mg/100g) (Table 2-A), but thought that the result was odd, since calcium is highly correlate with casein micelles (Lindmark-Månsson 2004). And the content of casein micelles had decreased in the milk composition (Fig. 1).

Furthermore, Table 2-A shows that the average calcium content had significantly increased in Swedish milk between 2001 and 2009 (113 vs. 119 mg/100g). Both seasonal and geographical differences were noted by Lindmark-Månsson (2012) in research from 2009. The calcium content was highest in January and lowest in July. Gothenburg had the highest calcium content in the milk in January meanwhile Jönköping, Kalmar and Malmö had the highest values in July (126 vs. 115 mg/100g). The lowest value in January was noted in Grådö and in July in Grådö and Stockholm (123 vs. 113 mg/100g) (Lindmark-Månsson 2012).

Calcium is also an important factor in cheesemaking. Nilsson *et al.* (2019) found that lower concentrations of both total calcium content and calcium ions (Ca^{2+}) are correlated to non-coagulating (NC) milk. Gustavsson *et al.* (2014) came to the same conclusion as Nilsson *et al.* (2019). Further, NC milk is known for impairing the rennet coagulation time (RCT), which is not desired in cheesemaking, since a shorter RCT is more favourable due to economically reasons, like optimization of the production. Gustavsson *et al.* (2014) concluded that the Ca^{2+} concentration and the total calcium content, together with the protein content and casein micelle size, were the most important factors to the variation of gelation properties. An easy way to improve the gelation properties in milk is to add calcium chloride ($CaCl_2$) (Ong *et al.* 2015). Another possible long-term way to improve the gelation properties in milk, is to breed for higher calcium content, since calcium has shown to have good heritability (Nilsson *et al.* 2019).

Ostersen *et al.* (1997) concluded that cheesemaking improved when milk from cows who were in their late stage of lactation was used, likely correlated to the protein and calcium content. The protein content is often higher in the late-lactation and even calcium content has reached its maximum in this stage. The same result was concluded in an Irish research. O'Keeffe (1984) stated that using milk from the late lactation is ideally for cheesemaking since that is when the casein and calcium content are highest.

3.6. Citric acid

In 2016, Sweden used 24% of all bovine milk to cheese production (Nilsson *et al.* 2019). Citric acid, also named citrate, as well as calcium, is an important component in cheese making. Together with phosphate, both components act as a melting salt, binds calcium and alter the texture of the cheese. Citrate also gives improved texture to yoghurt (Mekmene & Gaucheron 2011). A study by Priyashantha *et al.* (2019), concluded that addition of citric acid and calcium affects the average size and size distribution of casein micelles in bovine milk.

The citric acid content varies due to season and stage of lactation. The highest levels of citrate are during grazing period and in the beginning of the lactation (Garnsworthy *et al.* 2006; Priyashantha *et al.* 2019). In contrast, Lindmark-Månsson *et al.* (2003) studied the citric acid concentration in Swedish dairy milk and concluded only geographical variation and no seasonal variation. The citric acid content ranged from 0.182% in southern Sweden to 0.194% in the northern Sweden. Later, in 2009, Lindmark-Månsson (2012) studied the Swedish milk composition and found, similar as Priyashantha *et al.* (2019), both geographical and seasonal differences.

The data of the citric acid content in Swedish dairy milk is limited. Table 2-A shows that the average citric acid content in Swedish dairy milk significantly decreased between 1996 and 2009 from 0.190 mg/100g to 0.151 mg/100g. Lindmark-Månsson (2012) also reported seasonal variation in 2009, with the highest measured citric acid content in January and lowest in July.

Opposite results were found by Karlsson *et al.* (2017) who reported that citric acid content in raw milk did not show any significant difference between indoor and outdoor period.

Furthermore, Table 2-A highlights that the mean value of citric acid in Swedish raw milk was 0.205 mg/100g in 2015, which is a significant increase from 2009, when the citric acid content was measured to 0.151 mg/100g (Lindmark-Månsson 2012). Garnsworthy *et al.* (2006) reported that the citrate content varies with stage of lactation and is related to de novo synthesis of fatty acids, but independent of diet and milk yield. However, the findings in this thesis are based on silo milk, where the stage of lactation cannot be considered as a reason for the citrate variation. Those, other factors, not investigated, must co-vary to give the result obtained.

3.7. Somatic Cell Count

The somatic cell count (SCC) gives an indication of the cow's udder health and more than 200 000 cells/ml indicate a poor udder health, and the cow is suffering from subclinical mastitis (Växa Sverige 2018). Other factors like, stage of lactation, age, season, and stress, may influence the SCC in milk but has a minor impact compared to infections (Harmon 1994).

Växa performed tests of individual measurements of SCC from Swedish cows that were affiliated to their organization Kokontrollen in 2018/2019, and came to the conclusion that approximately 24% were suffering from subclinical mastitis (Växa Sverige 2018). It is known that udder health has several negative consequences. Firstly, when a cow is infected with clinical or subclinical mastitis, the milk yield will decrease. Secondly, SCC is one of the payment factors in Swedish milk, hence the high number of SCC in the milk, because of mastitis, will lower the income for the farmer. Thirdly, the farmer has to pay veterinary and medicine costs as the mastitis must be treated with antibiotics (Oskarsson 2010). Sum up of these three consequences is that a high SCC can cause significant financial losses for the farmer.

Table 2-A shows the variation of SCC in Swedish bulk-milk from 1996 (233 000 cells/ml) to 2019 (248 000 cells/ml). Växa Sverige reported a noticeable decrease of bulk-milk SCC in 2016/2017 (239 000 cells/ml). The bulk-milk SCC had increased again in 2017/2018 (245 000 cells/ml), which is an unfortune indication that the udder health has become worse (Växa Sverige 2018). A reason for the increase of SCC in 2017/2018 could be the hot summer in 2018. In a previous study on how heat stress impact milk quality, it was found that SCC increase in dairy cows during summers months (Summer *et al.* 2019).

Furthermore, the SCC varies during the year and within the country. A trend line made by Växa (not shown in this thesis) shows that the SCC is seasonal in Sweden and is often higher during summer and lower during winter. However, this trend was discontinued during 2018/2019 when the SCC increased during the indoor period (Växa Sverige 2018).

Sant' Anna & Paranhos da Costa (2011) in a Brazilian study investigated how the hygiene of dairy cows vary over time and whether a relationship exists between hygiene and SCC in outdoor cows. Their findings indicated the same trend as Växa, where the SCC was highest during the summer (January – March) and lowest during the winter (August). A possible reason for this finding was that the summer months coincided with periods of higher rainfall. Thus, more mud was present in the paddocks and had a negatively influence on cow's hygiene (Sant'Anna & Paranhos da Costa 2011).

Växa also reported a significant difference within the country. Västerbotten county had the lowest measured SCC in bulk-milk with approximately 200 000 cells/ml, meanwhile Blekinge, Uppland and Västmanland county are in the top with approximately 270 000 cells/ml (Växa Sverige 2018).

The easiest way to avoid a large number of SCC in the milk is to keep good hygiene. During an interview, Levin said that it is unlikely that cows will transmit mastitic bacteria through a milking robot, since the teat cups on the robot is cleaned between each milking (Levin 2020). If a cow is suffering from mastitis, it is more likely she will transmit the disease to the environment and from there to other cows. On the other hand, if farmers are milking their cows in a milking parlour, there is a potential risk mastitis is transmitted through the cups, if the farmer is not meticulous with cleaning the cups between milkings.

3.8. pH

The pH in milk is important for several reasons e.g. rennet coagulation time and heat stability (Phelan *et al.* 1982). Measurements of the pH may provide information if the cow is suffering from mastitis, subclinical mastitis or other diseases. pH tests are convenient for on-farm use and are considered as relatively low-cost tests (Kandeel *et al.* 2019).

The data of pH in Swedish bovine raw milk is limited. Lindmark-Månsson (2004, 2012) measured the pH content in Swedish bovine raw milk in 1996 and 2001 (6.74 vs. 6.58) and Karlsson *et. al* (2017) measured in 2015 the pH to 6.73 (Table 2-A).

Ultra-high temperature (UHT) treated milk is frequently used in other countries, like China (Liem *et al.* 2016) and France (Oupadissakoon *et al.* 2009), but less commonly used in Sweden. However, the pH is of high importance when it comes to processing of UHT milk. It is recommended that the pH should be between 6.65-6.70 to be suitable for the process, thus it is between that pH-range milk has its maximum heat stability (Karlsson *et al.* 2019).

One factor that can affect the milk pH is the feed composition. Russell (1998) concluded that cows that were given 90% concentrate had lower milk pH (6.22) compared to cows only fed forage (6.86).

In a research by Atasever (2010), the relationship between SCC and pH in bovine raw milk was determined. In this case, an increased SCC led to a decline of the pH, and consequently a higher level of acidity in the milk. Despite, the conclusion of the paper was that measuring of pH cannot indicate early subclinical mastitis in cows and the method should therefore not be used until more research has been implemented (Atasever *et al.* 2010).

3.9. Changes on Swedish farms and dairies

It is not only changes in the milk composition and properties that has occurred over the last decades. The Swedish dairy farms have gone through changes too.

Table 3-A shows the variation of descriptive parameters of Swedish dairy farms from 1996 to 2019. What is striking is the dramatic decline in number of dairy farms over the past 20 years. Since the millennium, Sweden has had an exponential reduction of dairy farms. In year 2000 there were 12 676 dairy farms, compared to 3 253 dairy farms in 2019 (Table 3-A).

The total number of cows has also decreased since 2000. However, even if there is a trend in reduced number of farms and cows, the trend also shows an increased number of cows on each farm. The Swedish dairy farms have more than doubled the average number of cows between 2005 to 2019 (46 vs. 94 cows) (Table 3-A).

Furthermore, Table 4-A shows that the average milk yield per cow has increased from 7 112 kg in 1996, compared to, 9 996 kg milk per year in 2019. Several factors affect the milk yield, e.g. environment, stage of lactation and breed (Sharma *et al.* 1988). SLB and Swedish Red Cattle (SRB) are the most common breeds and the breeds in Sweden that yield most milk, on average 10 551 vs. 9 245 kg/milk per cow and year, respectively. Meanwhile Jersey cattle and Swedish Mountain cattle and Swedish Red Polled cattle (SKB) generate a significantly lower yield, on average 7 144 vs. 5 700 kg/milk per cow and year, respectively. On the other hand, especially Jersey cattle, has a higher protein and fat content compared to both SLB and SRB (Växa Sverige 2020).

Table 4-A shows that the total milk yield in Sweden has had a negatively trend from 1996 to 2019. In 1996, the total milk yield was 3 258 000 tons and has since steadily declined, apart from 2010 – 2015. Between those years, the total milk yield in Sweden slightly increased (2 862 000 vs. 2 933 000 tons) (Jordbruksverkets statatistikdatabas 2020e). According to SMHI, the weather between 2010-2015 did not show any extreme variation, neither too hot nor too cold, apart from a cold winter in 2010 (Swedish Meteorological and Hydrological Institute 2017). Hence, the weather conditions were favourable for a possible increase of total milk yield.

The number of Swedish dairy plants has also showed a falling trend. Lindmark-Månsson (2004) reported 55 Swedish dairies in 1996 whereas only 31 dairies were reported in 2014. However, since 2015, the number of dairies has started to increase again. Jordbruksverket published a number of 38 dairies in 2015 and 48 dairies in 2018.

4. Discussion

This thesis shows that the composition and properties in Swedish raw milk are not constant and is influenced by several factors.

The average protein content in Swedish raw milk has steadily increased since the millennium, from 3.28 % in 2000 to 3.50 % in 2019. The main reason is due to changes in the composition of the feed (Karlsson *et al.* 2017; Li *et al.* 2019; Levin 2020). Swedish dairy cows have nowadays a higher percentage of protein coming from, beans and peas, in their feed ration than they had 15 years ago, dairy farmer Levin (2020) says.

The protein content has not only changed over time, it changes over seasons too, possibly because of changes in the feed. Research by Karlsson *et al.* (2017) and statistics from Jordbruksverkets statistikdatabas (2020d,b) (Fig. 2) shows that the protein content is lower in Sweden during June to August and higher during October and November. The silage the dairy cows are fed in October and November is from the first harvest and contains more protein than silage from harvest two and three (Levin 2020).

The average fat content has been more stable the last 20 years compared to the average protein content (Fig.1) but had a significantly decreased from 1995 to 2000 (4.33 vs. 4.18%). A possible reason is the feeding strategy.

The fat content in the raw milk follows the same seasonal pattern as the protein content. The fat content is lower during June-August and higher in October-November.

In contrast to protein and fat, lactose is the component in milk that stays most stable during the season (Heck *et al.* 2009). In the last decades, the average lactose content in Swedish milk has been around 4.7-4.8% (Lindmark-Månsson 2004, 2012)

The trend shows that the average calcium content of Swedish milk is increasing. Lindmark-Månsson (2012) reported both seasonal and geographical variations in the calcium content in 2009. The calcium content was highest in January and lowest in July, respectively. Both O'Keeffe (1984) and Ostersen *et al.* (1997) concluded that using milk from dairy cows in their late lactation is ideal for cheesemaking because that is when the calcium content has reached its maximum and the protein content is often high in the late lactation too.

Research on geographical and seasonal variations of citrate showed different results. Priyashantha *et al.* (2019) found both seasonal and lactation differences in citrate, meanwhile Lindmark-Månsson *et al.* (2003) only found geographical but no seasonal variations. Lindmark-Månsson (2012) performed further studies in 2009 and found both geographical and seasonal variations of citrate.

Data on the average citrate content in Swedish milk has been limited but showed a decrease between 1996 and 2009, from 0.190 mg/100g to 0.151 mg/100g. Followed by an increase from 2009 to 2015 from 0.151 mg/100g to 0.205 mg/100g. Stage of lactation cannot be considered as a reason to the variation in citrate content, since the findings in this thesis are based on silo milk. Those, other factors, not investigated, must co-vary to give the results obtained.

The SCC gives an indication of the cow's udder health. The most recent data on SCC of Swedish milk shows cell counts around 240 000 cells/ml (Växa Sverige 2018). Växa reported seasonal variations in SCC. With a higher SCC level during summer and lower during winter. Sant' Anna & Paranhos da Costa (2011) came to the same conclusion. A possible reason for this finding was that the summer months coincided with less hygienic management, due to outdoor period. So, the most likely reason why Swedish dairy cows have less SCC in their milk during winter is because they have their indoor period then, which leads to less exposure of mud. Research shows that the easiest way to keep the number of SCC in milk to lower levels is to keep a good hygiene of the cows (Andersson *et al.* 2011).

A lot of changes have appeared on the Swedish dairy farms since 1995, as summarized in Table 3-A. The number of dairy farms and the total number of dairy cows have decreased. The average number of dairy cows per farm have instead increased from 33 to 94 cows (1996 vs. 2019). This means that the Swedish dairy producers have become fewer but have a larger herd size compared to 1996. The total milk yield has also increased from 7 112 to 9 996 (1996 vs. 2019). On an overall scale, Table 4-A shows that the total milk yield in Sweden has decreased.

A likely reason to the decrease of dairy farms and increased herd size is that farmers have not been able to make a profitability with a small herd size (Sjöblom 2020). If the current trend continues, Sweden will have less cows on pasture and a consequence of that will be a decrease of the biodiversity.

Furthermore, with a decrease of dairy farms, less job opportunities within the agriculture sector will be available, which is sad if Sweden wants broad the knowledge about Swedish dairy farming (Sjöblom 2020).

5. Conclusions

The overall aim of this thesis was to investigate the variation of Swedish raw milk quality (i.e. composition and properties) over the last 25 years. In conclusion, research shows that the milk quality is affected by several on-farm factors: breed, stage of lactation, number of lactations, feed composition, and climate. This thesis concludes that since year 2000 the protein content in Swedish raw milk has significantly increased to an average protein content today of 3.5 %. The most likely reason to the increase in the protein content is the feed composition, since Swedish dairy cows nowadays are fed with more legumes. Meanwhile the fat content has been stable around 4.2 %. Warm and dry summers have negative impact on the milk quality, affecting both the protein and fat content. Long term heat makes the cows stressed and stress has shown to decrease the protein and fat content in milk. Raw data of lactose, calcium, citrate, and pH have been limited. Overall, the Swedish milk composition and properties have altered, with an average increase in calcium, citrate, and SCC and a decrease in lactose content over the last 25 years, while pH has been nearly constant through the years.

6. Further investigations

This thesis is the latest study, which the author is aware of, to summarize a larger amount of data of Swedish raw milk quality since Lindmark-Månssons (2012) reported. The author suggests that further compilations of raw data within this topic are necessary. It would be interesting to strengthen the national platform to analyse and collect comprehensive and systematic raw milk data from various regions in Sweden in each year for further studies. Such milk recording must investigate detail compositional and properties in milk, other than conventional parameters. Identifying such trends will enable to predict the variation milk quality and design the breeding programmes accordingly. The milk quality is important for the dairy industry to be able to produce different dairy products; good milk quality has also got more competitive advantages on the market. Research within this topic gives an indication on the dairy cows udder health, changes in dairy farms, and emphasis the need of national milk and farm quality control programmes.

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Britt – Lis Levin, Swedish Dairy Farmer, Bjäsäter gård, Östergötland county, Sweden, Interview: 2020-04-16 Time: 14.40 – 14.59

Tomas Andersson, Husdjursagronom (Animal Science Agronomist), Sweden, Interview: 2020-07-16 Time: 13.09 – 13.44

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Appendix

Table 1-A: Average protein and fat content in Swedish bovine raw milk from 1995 to 2019

Year	Protein (%)	Fat (%)
1995	3.34	4.33
1996	3.33	4.29
1997	3.32	4.28
1998	3.31	4.26
1999	3.30	4.19
2000	3.28	4.18
2001	3.28	4.20
2002	3.32	4.17
2003	3.35	4.22
2004	3.38	4.25
2005	3.38	4.25
2006	3.38	4.22
2007	3.40	4.23
2008	3.38	4.21
2009	3.40	4.24
2010	3.41	4.23
2011	3.41	4.20
2012	3.42	4.22
2013	3.42	4.26
2014	3.42	4.25
2015	3.42	4.25
2016	3.45	4.24
2017	3.47	4.21
2018	3.46	4.20
2019	3.50	4.24

Source: *Jordbruksverkets statistikdatabas (2020)*

Table 2-A: Variation in Swedish bovine raw milk components from 1995 to 2019

Year	**Lactose**	**Calcium (mg/100g)**	**pH**	**Cell count (cells/ml)**	**Citric acid (g/100g)**
1996	4.80[1]	114[1]	6.74[1]	233 000[1]	0.190[1]
1997	N/A	N/A	N/A	N/A	N/A
1998	N/A	N/A	N/A	N/A	N/A
1999	N/A	N/A	N/A	N/A	N/A
2000	N/A	N/A	N/A	N/A	N/A
2001	4.82[1]	113[1]	6.58[1]	203 000[1]	N/A
2002	N/A	N/A	N/A	N/A	N/A
2003	N/A	N/A	N/A	N/A	N/A
2004	N/A	N/A	N/A	N/A	N/A
2005	N/A	N/A	N/A	229 000[4]	N/A
2006	N/A	N/A	N/A	229 000[4]	N/A
2007	N/A	N/A	N/A	N/A	N/A
2008	N/A	N/A	N/A	N/A	N/A
2009	4.73[2]	119[2]	N/A	223 000[4]	0.151[2]
2010/2011	N/A	N/A	N/A	243 000[4]	N/A
2011/2012	N/A	N/A	N/A	248 000[4]	N/A
2012/2013	N/A	N/A	N/A	245 000[4]	N/A
2013/2014	N/A	N/A	N/A	246 000[4]	N/A
2014/2015	N/A	N/A	N/A	246 000[4]	N/A
2015/2016	4.72[3]	120.5[3]	6.73[3]	249 000[4]	0.205[3]
2016/2017	N/A	N/A	N/A	239 000[4]	N/A
2017/2018	N/A	N/A	N/A	245 000[4]	N/A
2018/2019	N/A	N/A	N/A	248 000[4]	N/A

Source:
[1] *Lindmark-Månsson (2004)*
[2] *Lindmark-Månsson (2012)*
[3] *Karlsson et al. (2017)*
[4] *Växa Sverige (2018)*

Table 3-A: Variation of descriptive parameters of Swedish dairy farms from 1996 to 2019

Year	Total number of cattle in Sweden	Number of dairy farms	Average number of cattle per farm
1996	466 000[1]	16 000[1]	33[1]
1997	N/A	N/A	N/A
1998	N/A	N/A	N/A
1999	N/A	N/A	N/A
2000	N/A	12 676[2]	N/A
2001	418 000[2]	11 828[2]	39[2]
2002	417 000[2]	11 270[2]	37[2]
2003	402 520[2]	9 720[2]	41[2]
2004	403 702[2]	9 147[2]	44[2]
2005	393 263[2]	8 548[2]	46[2]
2006	387 530[2]	8 027[2]	48[2]
2007	369 646[2]	7 096[2]	52[2]
2008	357 194[2]	6 474[2]	55[2]
2009	356 776[2]	6 020[2]	59[2]
2010	348 095[2]	5 619[2]	62[2]
2011	346 495[2]	5 260[2]	66[2]
2012	347 969[2]	4 968[2]	70[2]
2013	344 021[2]	4 668[2]	74[2]
2014	344 339[2]	4 394[2]	78[2]
2015	339 823[2]	4 169[2]	82[2]
2016	330 833[2]	3 872[2]	85[2]
2017	322 010[2]	3 614[2]	89[2]
2018	319 387[2]	3 477[2]	92[2]
2019	305 570[2]	3 253[2]	94[2]

Sources*:*

[1] *Lindmark-Månsson (2004)*

[2] *Jordbruksverkets statistikdatabas (2020)*

Table 4-A: Milk yield and number of Swedish dairies

Year	Total milk yield (kg per cow and year)	Total milk yield in Sweden (1000 tons)	Number of dairies in Sweden
1995	7 757[1]	3 243[2]	57[3]
1996	7 809[1]	3 258[2]	55[4]
1997	7 989[1]	3 276[2]	N/A
1998	8 103[1]	3 277[2]	N/A
1999	8 272[1]	3 299[2]	N/A
2000	8 537[1]	3 297[2]	50[3]
2001	8 742[1]	3 290[2]	49[4]
2002	8 784[1]	3 226[2]	45
2003	8 794[1]	3 206[2]	43
2004	8 994[1]	3 229[2]	38
2005	9 040[1]	3 163[2]	37[3]
2006	9 108[1]	3 130[2]	N/A
2007	9 214[1]	2 986[2]	N/A
2008	9 162[1]	2 987[2]	N/A
2009	9 285[1]	2 933[2]	36[3]
2010	9 221[1]	2 862[2]	35[3]
2011	9 210[1]	2 850[2]	34[3]
2012	9 261[1]	2 861[2]	33[5]
2013	9 244[1]	2 868[2]	32[6]
2014	9 445[1]	2 931[2]	31[7]
2015	9 611[1]	2 933[2]	38[8]
2016	9 759[1]	2 862[2]	48[8]
2017	9 801[1]	2 816[2]	45[9]
2018	9 827[1]	2 760[2]	48[10]
2019	9 996[1]	2 704[2]	N/A

Sources:

[1] *Växa Sverige (2020)*

[2] *Jordbruksverkets statistikdatabas (2020)*

[3] *Jordbruksstatistik årsbok (2012)*

[4] *Lindmark-Månsson (2004)*

[5] *Jordbruksstatistik årsbok (2013)*

[6] *Jordbruksstatistik årsbok med data om livsmedel (2014)*

[7] *Jordbruksstatistik sammanställning med data om livsmedel-tabeller (2015)*

[8] *Jordbruksstatistik sammanställning med data om livsmedel-tabeller (2017)*

[9] *Jordbruksstatistik sammanställning med data om livsmedel-tabeller (2018)*

[10] *Jordbruksstatistik sammanställning med data om livsmedel-tabeller (2019)*

Table 5-A: Average fat content in June (M06), July (M07) and August (M08) from 1995 to 2019. Highlighted numbers are described in sub-chapter 3.2.3.

Year and month	Fat content (%)
1995 M06	4.29
1995 M07	4.21
1995 M08	4.14
1996 M06	4.23
1996 M07	4.18
1996 M08	4.13
1997 M06	4.18
1997 M07	4.11
1997 M08	4.07
1998 M06	4.19
1998 M07	4.15
1998 M08	4.15
1999 M06	4.13
1999 M07	4.05
1999 M08	4.05
2000 M06	4.10
2000 M07	4.07
2000 M08	4.07
2001 M06	4.11
2001 M07	4.06
2001 M08	4.06
2002 M06	4.08
2002 M07	3.99
2002 M08	3.95
2003 M08	4.15
2003 M06	4.06
2003 M06	4.06
2004 M07	4.17
2004 M08	4.14
2004 M06	4.11
2005 M06	4.17
2005 M07	4.09
2005 M08	4.13
2006 M06	4.11
2006 M06	4.04
2006 M07	4.06
2007 M08	4.11
2007 M06	4.09
2007 M06	4.10
2008 M07	4.11
2008 M08	4.08

2008 M06	4.04
2009 M06	4.17
2009 M07	4.11
2009 M08	4.12
2010 M06	4.13
2010 M07	4.05
2010 M08	4.07
2011 M06	4.12
2011 M07	4.04
2011 M08	4.08
2012 M06	4.14
2012 M07	4.10
2012 M08	4.11
2013 M06	4.23
2013 M07	4.23
2013 M08	4.23
2014 M06	4.22
2014 M07	4.21
2014 M08	4.21
2015 M06	4.23
2015 M07	4.22
2015 M08	4.23
2016 M06	4.14
2016 M07	4.09
2016 M08	4.15
2017 M06	4.12
2017 M07	4.07
2017 M08	4.04
2018 M06	4.06
2018 M07	4.03
2018 M08	4.04
2019 M06	4.12
2019 M07	4.11
2019 M08	4.16

Source: *Jordbruksverkets satistikdatabas* (2020)