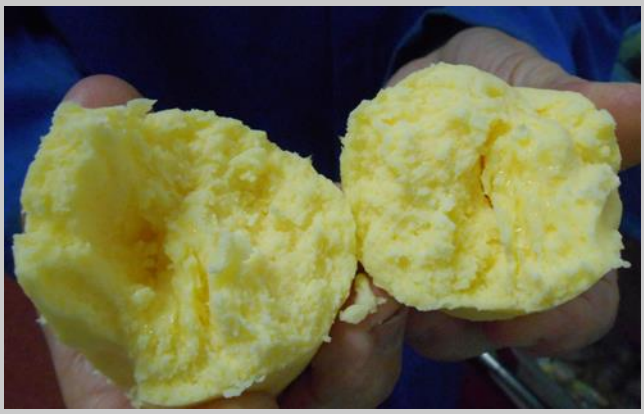
Project report

Sensory quality and shelf life of traditional butters compared to high quality industrially produced butters



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1. Introduction

In UK's consumer perception, food sold locally by small manufacturers e.g. farmer's markets is fresher, tastier and might be of higher quality than the produce retailed in supermarkets (McEachern et al., 2010; Spiller, 2012). Farmers' markets offer a range of artisan and traditional foods that are uncommon in supermarkets and these products are perceived by consumers as made with more care and thus are highly valued (Autio et al., 2013).

Despite modern consumer's interest in farmer's markets, traditional and locally sourced foods information on the quality and shelf-life of such produce is very limited.

An example of such a food product is traditional butter. Traditional butter is perceived as a luxury product and seems to be valued for special sensory attributes by consumers and restaurants (Higgins and Patterson, 2013). Although there is no information available on traditional butter consumption or sales in UK, online search revealed that there are several farm shops trading the product that can be found online. The web descriptions of the traditional butter indicate that it is a product that is made by a farmer from the milk of their own cows, often by hand. However, it is not well understood how this traditional process differs from a large scale industrial process.

From a previous short consultancy research work that was conducted at National Centre for Food Manufacturing we have found that a sample of traditional butter carried more than 100.000 total microorganism count in 1 g of product. Typically the butter should carry only up to 1000 microorganisms in 1 g (Adams and Moss, 2008), although this might vary for butters made from a cultured cream (Neaves and Langridge, 1998). Despite an uncertain reason for this particular sample carrying a high microbiological count, it can be speculated that the increased number of production steps and prolonged operation times required to make butter by hand may be a contributing factor. Some authors also mention that in a very traditional butter production where the wooden churners could be used, microbiological contamination of butter might be increased. This is due to difficulty of sanitising wood compared to stainless still or aluminium churners (Budkhar et al., 2014).

The introduction of microbiological contamination during butter manufacture is likely to reduce its shelf life.

Butter generally carries a low microbiological load as most of the water containing microbes is separated out in the production process (Adams and Moss, 2008) Furthermore butter provides only very low concentrations of nutrients for microorganisms, limiting growth of many (Adams and Moss, 2008). Despite this, microbiological spoilage of butter may have place due to contamination with bacteria of genus *Pseudomonas spp.* as well as some yeasts and moulds that are able to survive and grow at low temperatures (Budkhar et al., 2014).

The main reason for the termination of the butter's shelf life is a development of the fat rancidity. Fat rancidity progresses with the butter storage and is a result of oxidation as well as lipolytic activities of microbiological and originating from milk enzymes (Munro et al., 1998). Level of the fat degradation is related to butter's sensory quality (Munro et al., 1998; Champagne et al., 1994) and thus requires monitoring in studies on quality and shelf-life of butter.

The aim of this study was to conduct sensory, chemical and microbiological analysis on traditional butters and compare it to high quality industrially produced butter in order to answer three questions: 1. Is the sensory quality of traditional butters superior to industrial butters? , 2. Does traditional butter spoil faster than industrial butter? 3. What are the reasons for any differences between traditional and industrial butters?.

This study was performed after visiting and collecting samples from three traditional butter manufacturers and one large scale butter producer. During these visits it was possible to observe the butter making processes and find out what the "traditional butter production" really meant.

2. Materials and methods

2.1 Butter samples

Traditional butter samples were collected from three manufacturers (A, B and C). Five traditional butters were collected. Three different butters from a single industrial butter manufacturer (D) were also collected. Traditional butters were made of different types of cream. Unsalted and salted butters were collected and salted butters contained different levels of added salt. One industrial butter contained additives that according to the manufacturer were aimed to give the product sensory traits of the butter made of a cultured cream. Butter characteristics were summarised in Table 1.

Table 1- Characteristic of collected butter samples

Sample identification	Factory	Declared salt content	Cream type used for production	Other additives
AU	A	None	Whey	None
BU	B	None	Sweet*	None
BS	B	0.5%	Clotted	None
CS	C	1.5%	Sweet*	None
CS1	C	2%	Whey and Sweet*	None
DU	D	None	Sweet*	None
DU1	D	None	Sweet*	Lactic Acid and Diacetyl
DS	D	2%	Sweet*	None

*Sweet refers to pasteurised, uncultured cream

2.2 Sensory analysis

Butter samples were stored for 24 h at 12˚C (ISO 22935-2, 2009), and were subjected to the sensory evaluation right after removing from this refrigerated storage.

Sensory quality of the butters was evaluated using a panel of 15 untrained volunteers, instructed on how to perform the butter analysis directly prior to the test. The test was designed according to ISO 22935-2:2009. Volunteers were requested to assess following traits of each butter: odour, appearance, flavour and consistency in a given order, using 5 point scale. The scale was composed of following scores

1- For dislike very much
2- For dislike a little
3- For not sure
4- For like a little
5- For like very much

Based on the results of the sensory analysis an overall score for each butter was calculated. This score was obtained by multiplying a score for each assessed trait by an assigned importance coefficient and summing the result of all the traits up in a single score. The assigned importance coefficients for individual traits were based on a previously published work on sensory evaluation of the butter (Czechowska-Liszka, 2005). The coefficients were individually for: odour- 0.3, appearance- 0.1, flavour- 0.4 and consistency- 0.2.

The volunteers were also asked to rate butter samples from the one they liked best to the one they liked the least. It was possible to assign a same score to multiple butter samples if they were of similar desirability.

Salted and unsalted butters were evaluated separately, starting with unsalted butters.

2.3 Chemical analyses

Peroxide and acid values of butter fats were evaluated following procedures described by Krause (2008) with some modifications. Butter oil was separated from butter by liquidising samples in a 50˚C water bath for less than 10 min and subsequently centrifuging at 14 500 rpm for 5 min in MiniSpin Plus centrifuge with F-45-12-11 rotor in 1.5. ml tubes (Eppendorf, Hamburg, DE). Oil from 2-3 tubes was combined in a single conical flask of known weight for acid or peroxide value evaluation. Then samples were weighted and analysed as described below.

In preparation for titrimetric peroxide value evaluation a butter oil sample was dissolved in chloroform (10 ml). Then glacial acetic acid (15 ml) and freshly prepared saturated potassium iodide solution (1ml) were added and the sample was shaken by hand for 1 min, then kept in the darkness for exactly 1 min. Subsequently deionised water (75 ml) and freshly prepared 1% starch solution (about 1 ml) were added. Thus prepared sample was titrated with 0.002 M sodium thiosulfate till blue colour disappeared. Peroxide value was calculated according to the equation 1.

$$\boldsymbol{PV = \frac{V_{st} \times M_{st} \times 1000}{m}} \qquad 1$$

Where:

PV- peroxide value (mEq of peroxide/kg of oil)

V_{st}- volume of sodium thiosulfate used for titration (ml)

M_{st}- molarity of sodium thiosulfate

m- weight of the sample (g)

For the acid value determination solid oil samples were briefly (<1 min) heated in a 50˚C water bath till liquid, then dissolved in 50 ml of 1:1 (v:v) mixture of absolute ethanol and diethyl ether with added 1 ml of 1% phenolphthalein indicator and neutral pH (adjusted with 0.1 M sodium hydroxide). Sample was then titrated with 0.025 or 0.05 M NaOH till development of pink colour that was stable for a minimum of 1 min. Acid value was calculated according to the equation 2.

$$\boldsymbol{AV = \frac{V_{sh} \times M_{sh} \times 40}{m}} \qquad 2$$

Where:

AV- acid value (NaOH/g of oil)

V_{sh}- volume of sodium hydroxide used for titration (ml)

M_{sh}- molarity of sodium hydroxide

m- weight of the sample (g)

Peroxide and acid values were estimated for fresh and stored for 8, 12, 18 and 24 weeks samples at 5˚C. Term fresh butter refers to up to 1 week old butter supplied by the factories and stored in frozen conditions to the day of analysis.

Moisture and fat content were evaluated using gravimetric method. To measure moisture content-weight loss after drying, samples were dried for 24 h at 103˚C. Dry samples were then subjected to fat extraction using Soxtec System HT 1043 Extraction Unit (Tecator LTD, Denton, Manchester, UK) with 1:1 v:v mixture of dietyl and petroleum ethers. Fat content was calculated based on the extract weight.

Water activity was measured using AquaLab Series 3 TE water activity meter (Labcell LTD, Four Marks, Alton, UK). Average temperature of the samples during this measurement was 21˚C.

All analyses were performed in triplicate.

2.4 Butter colour assessment

Colour measurements performed by means of Chromameter CR-400 (Konica Minolta, Tokyo, Japan) colorimeter. Values for lightness (L*) green to red (a*) and blue to yellow (b*) as specified by International Commission on Illumination (International Commission on Illumination, 2004) were obtained. For the purpose of this study only L* values were evaluated.

2.5 Microbiological analyses

Butter samples were prepared for microbiological analyses following ISO 6887-2 2003 (ISO 6887-2, 2003) method. Prior to enumeration, butter samples were suspended in Buffered Peptone Water (10 g of sample in 90 ml of liquid) and homogenised at 250 rpm for 2 min in Stomacher® 400 Circulator (Seward LTD, Worthing, UK). Obtained homogenate (neat or diluted as necessary) was then subjected to microbiological analysis.

All samples were analysed for initial contamination (within 1 week from production) with total viable count (TVC), Enterobacteriaceae, *Pseudomonas spp.* and yeast and moulds. All of these analyses with exception of Enterobacteriaceae were also carried out for samples stored at 5 ˚C for 8, 12, 18 and 24 weeks. Enterobacteriaceae and TVC were enumerated according to ISO 21528-2 2004 and ISO 4833-2 2013 methods respectively. *Pseudomonas spp.* were enumerated on Cetrimide-Fucidin-Cephalosporin *Pseudomonas* agar and yeast and moulds were enumerated on Rose Bengal Chloramphenicol agar. Both organisms were enumerated after media incubation at 25˚C for 48 (*Pseudomonas spp.*) and 120 hours (yeast and moulds).

All microbiological media were purchased from Oxoid (Altrincham, UK). All microbiological analyses were conducted in triplicate.

2.6 Water dispersion

Butter samples prior to water dispersion evaluation were kept for 24 h at 13˚C (as recommended by standard (IDF 112A, 1989)) and then cut with a thin knife. An indicator paper (Dysperwody, Lablacta, Olsztyn, PL) was then attached to a freshly uncovered butter surface, gently pressed and removed to read results. Indicator papers used in the study were infused with a colourant that stained the paper when in contact with moisture of the butter. The size and total area of the droplets visible on the paper were then used to assess the water dispersion in the butter as specified by the manufacturer of the indicator papers and given in Table 2.

Table 2- Water dispersion in butter according to Lablacta

Score	Result shown on indicator paper	
	Approximate size of the moisture drops (mm)	**Approximate area of the paper covered by the moisture drops**
Very bad	3 to 8	20%
Bad	1 to 3	10%
Sufficient	0.3 to 1	5%
Good	No moisture drops visible	0

2.7 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 21. Significance level for all of the tests was $p<0.05$. Different statistical tests were used for different data sets. Tests to which data were subjected were mentioned in captions to figures or tables where the results were summarised and in text where appropriate.

Mean increase or growth rates were given as a slope of linear fit to the microbiological growth curves (in $\log_{10}$ cfu g^{-1}) or evolution of peroxide and acid values measured over 24 weeks of storage.

Microbiological counts under the limit of detection were included into the statistical analyses and presented results as half of the value of the analytical detection limit expressed as cfu g^{-1}. The $\log_{10}$ cfu g^{-1} values of the detection limit were then 1.7 for *Pseudomonas spp*., TVC and yeast and moulds and 0.7 for Enterobactericaeae.

3. Results and discussion

3.1 Production process of traditional and industrial butters, defining traditional production

Generally production of butters in a traditional and industrial way varied in production scale and the way butters were churned and formed. The traditional churning required filling and emptying the churner after each butter production batch whereas the industrial churning was a process in which cream was continuously and automatically aspirated to the churner. In an industrial production the churned butter did not require washing with water, conversely to the traditional production. This and a full automation of industrially produced butter were making the whole process much shorter (2 to 6 times) compared to the traditional butter making.

Butter forming in the traditional set-up was done by hand (AU, BU, BS), semi (CS) or full-automation (CS1) while in the industrial process it was fully automated. Two out of three traditional butter manufacturers were using wooden scotch hands for butter forming (A and B), but churners in all establishments were made of easily washable materials, such as aluminium or stainless steel. Temperature of a finished butter product prior to forming was similar in between industrial and traditional processes (about 15˚C), whereas cream storage temperature and time depended on the individual manufacturers. Further details of the butter manufacturing were summarised in

Table 3.

Table 3- Butter production parameters

Production step	Manufacturer			
	A	B	C	D
Cream storage temperature (˚C)	5	5	5	8
Cream storage time (days)	Up to 3	Up to 2	Up to 5 if stored in silo and up to 12 if stored in pallecon	Up to 2
Maximum volume of the cream for a single churning (l)	135	10	1000	Continuous production
Temperature of the cream admitted to the churner (˚C)	10-12	10	5	8
Churning time (min)	20-70	12-15	45	Not specified
Buttermilk separation	Drained by opening churner's bottom valve, butter is then washed with water	Drained by opening churner's bottom valve, butter is then washed with water	Drained by opening churner's bottom valve, butter is then washed with chilled water	Drained by application of filters on walls of the churner and subsequent two compartments of the system where butter is mixed and kneaded, additionally first of these two compartments applies vacuum to help draining buttermilk
Mixing salt and additives	In a churner while kneading	In a churner while kneading	Upon the transfer to a separate mixing unit equipped with a stirrer	Within one of the system's compartments
Approximate duration of the process (min)	90 to 120	40	120	20
Butter temperature prior to forming (˚C)	15	15	9-15	15-16
Butter forming	250 g portions are weighted and rolled by hand, then formed using	250 g portions are weighted and rolled by hand, then formed using	200-250 g portions are automatically extruded and cut by hand or automatically	25 kg portions automatically extruded

Production step	Manufacturer			
	A	B	C	D
	wooden scotch hands	wooden scotch hands		
Packaging	By hand in cellophane	By hand in cellophane	By hand or automated in combined laminate material	Automated in a cardboard box lined with polyethylene bag
Claimed shelf-life (weeks)	12	4	8	12 for unsalted and 24 for salted butter

3.2 Sensory quality of traditional and industrial butters

Results of sensory assessment of traditional and industrially produced butters were shown in Figure 1. Statistically significant differences for flavour and odour as well as overall score were found in between unsalted butters. Traditional butter BU got highest scores while another traditional butter (AU) and industrially made butter (DU) lowest. Another industrially made butter DU1 got slightly, but not significantly lower score compared to BU. The most favourably perceived unsalted butter was BU (8 out of 15 participants nominated it as the one they liked the most) followed by AU (4 nominations), DU1 (3 nominations) and DU (2 nominations).

Results of sensory assessment of unsalted butters suggested that the traditional manufacture of a sweet cream butter allowed to obtain a product that was perceived more favourably by the consumers. Nevertheless addition of lactic acid and diacetyl within the industrial manufacture of a sweet cream butter resulted in a product that was perceived nearly as good. Traditional whey cream butter (AU) received slightly lower scores compared to the traditional sweet cream butter (BU) but it was perceived equally good as two industrially made butters and chosen a second best liked by the consumers butter. Whey cream butters, such as AU are known to have different odour compared to the sweet cream butters (Jinjarak et al., 2006), hence a difference in sensory assessment of these two types of butter was expected. The sensory analysis results indicated that the whey cream butter is also favourably perceived by the consumers and by some even more favourably than a sweet cream butter.

No differences in odour, flavour and overall score between salted butters were noted. Generally this result indicated that the addition of salt masks differences that can be perceived due to use of a different cream or a process for butter production. One sample (BS) scored significantly lower for the appearance than the other samples. This sample was characterised with a darker colour (lower L* value) than the other samples (see Figure 2) and had visible drops of accumulating moisture. Intense colour of the butter may be perceived as a positive trait as darker butters tend to have higher content of natural colours such as carotene and lycopene. These colours are associated with feed of the cows. Fresh grass fed cows will produce milk with higher content of the natural colours than hay or dry feed fed cows (Nozière et al., 2006). Hence, butter made of such milk may be perceived as more desirable by the consumers. Traditional butters were generally characterised by a darker colour compared to the industrial butters (see Figure 2), nevertheless their appearance was not scored any differently with exception of BS sample. Hence, it is likely that the moisture visible on the BS butter was the reason for lower scores for appearance.

The most favourably perceived salted butter was industrially produced DS (7 out of 15 participants nominated it as the one they liked the most) followed by all traditionally made butters CS1 (6

nominations), CS (3 nominations) and BS (2 nominations). Two best perceived butters had a higher added salt level (2%) compared to two butters with lower desirability (BS had 0.5% and CS 1.5%). Hence, it can be concluded that the salt level in salted butters is responsible for sensory desirability.

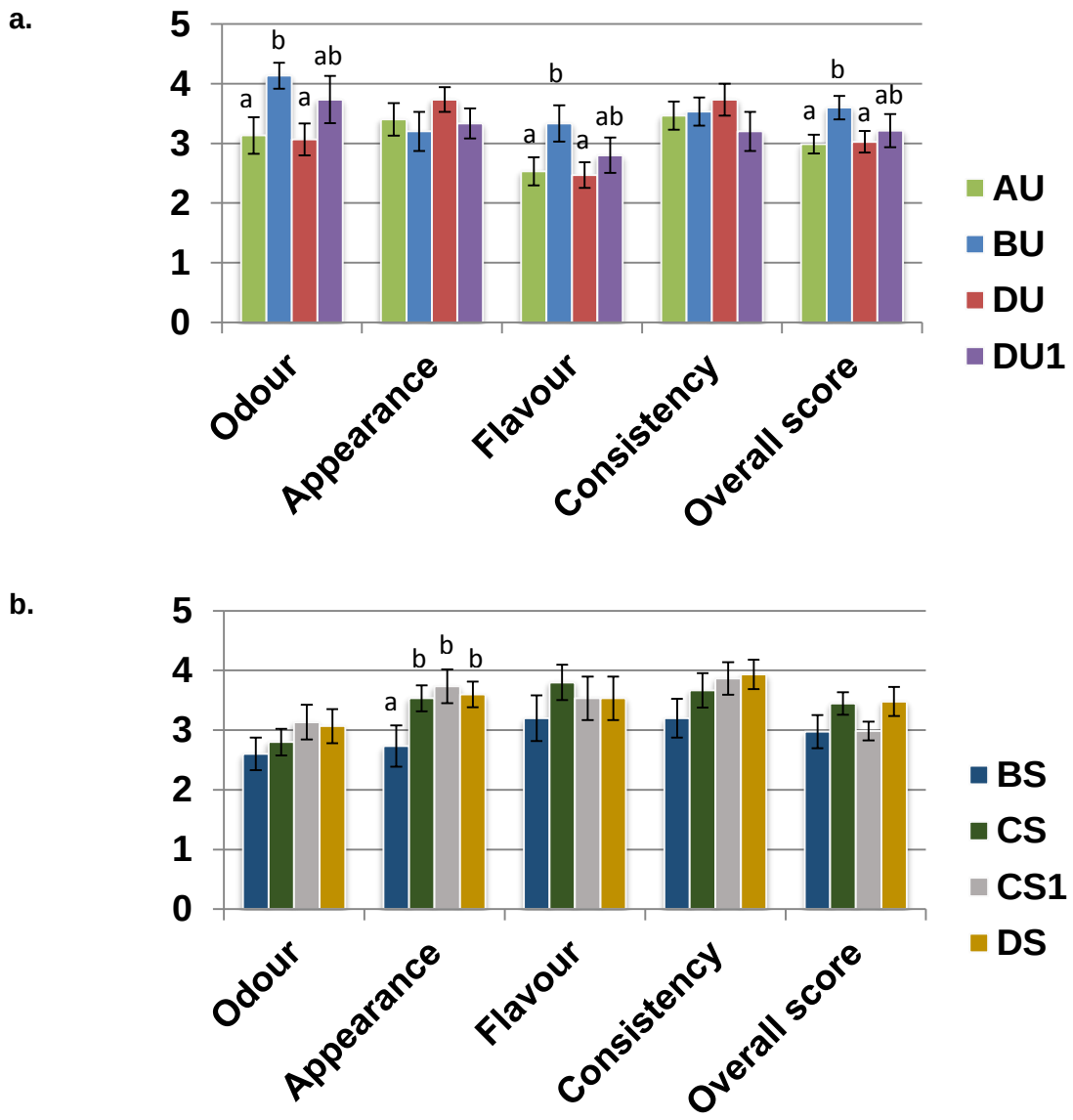

Figure 1- Results of the sensory evaluation of unsalted (a) and salted (b) butters in a 5 point scale. Error bars represent standard errors, while columns mean scores. Different letters above different columns belonging to the same butter trait mark a statistically significant difference

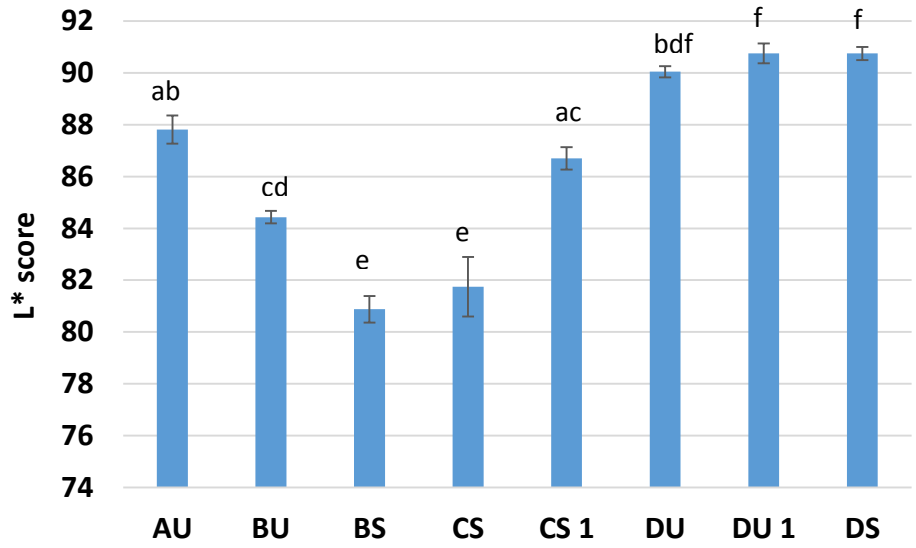

Figure 2- L values for butter samples. Columns correspond to the mean L* values while error bars to the standard error. Different letters above different columns mark a statistically significant difference ($p<0.05$ ANOVA and Tukey post-hoc)..*

3.3 Microbiological quality and shelf-life of traditional and industrial butters

3.3.1 Initial microbiological contamination

Initial microbiological contamination on the samples of collected butter was presented in Figure 3.

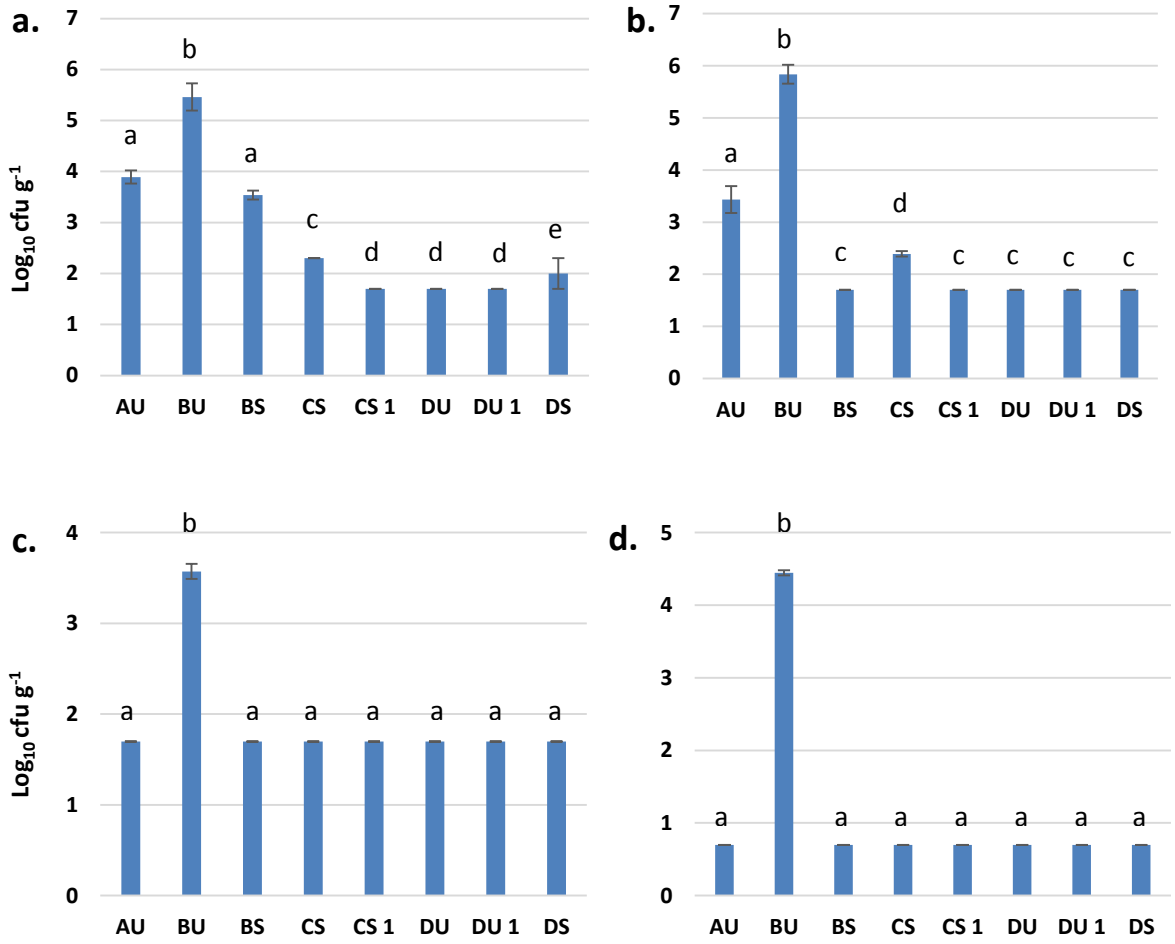

Figure 3- Initial microbiological load on butter samples with respect to (a) TVC, (b) Pseudomonas spp., (c) yeast and moulds, (d) Enterobacteriaceae. Columns correspond to the mean microbiological count while error bars to the standard error. Different letters above different columns in the same graph mark a statistically significant difference (p<0.05 ANOVA and Tukey post-hoc).

There were statistically significant differences in the initial microbiological load on the industrial and traditional butters (MANOVA $p<0.05$). The levels of microbiological contamination differed between butter manufacturers and for TVC and *Pseudomonas spp.* were highest on samples from the manufacturer B, followed by A, C and D (MANOVA with ANOVA and Tukey post-hoc $p<0.05$). The highest count of all the microorganisms was found on the sample BU, while samples CS 1, DU and DU 1 were characterised with a lowest count, which was below the limit of detection. In remaining samples Enterobacteriaceae and yeast and moulds were not detected, but various levels of TVC and *Pseudomonas spp.* (ranging from under the limit of detection to 3.89 $\log_{10}$ cfu g^{-1}) were found.

Two out of 5 traditional butters and all industrial butters satisfied guided microbiological criteria of no more than 3 $\log_{10}$ cfu g^{-1} for TVC in freshly manufactured butter (Adams and Moss, 2008). Only one sample (BU) had a TVC count above 5 but less than 7 $\log_{10}$ cfu g^{-1} which according to Health Protection Agency was a level that may indicate a need of further investigation into sources of butter

contamination (Health Protection Agency, 2009). This sample also did not meet criterion of maximum advisable level during butter's shelf-life for Enterobacteriaceae of 4 $\log_{10}$ cfu g^{-1} (Stannard, 1997). *Pseudomonas spp.* counts on this butter were also high (5.84 $\log_{10}$ cfu g^{-1}). This group of bacteria multiplies rapidly compared to others in refrigerated dairy (Fernandes, 2009b). Hence it can be concluded that either time or temperature of cream storage prior to butter production could have compromised microbiological quality of this butter.

3.3.2 Microbiological growth during refrigerated storage

Full set of growth curves for each of the tested microorganisms on each butter sample was given in the supplementary information. Mean growth rates of microorganisms on individual butters were presented in Figure 4.

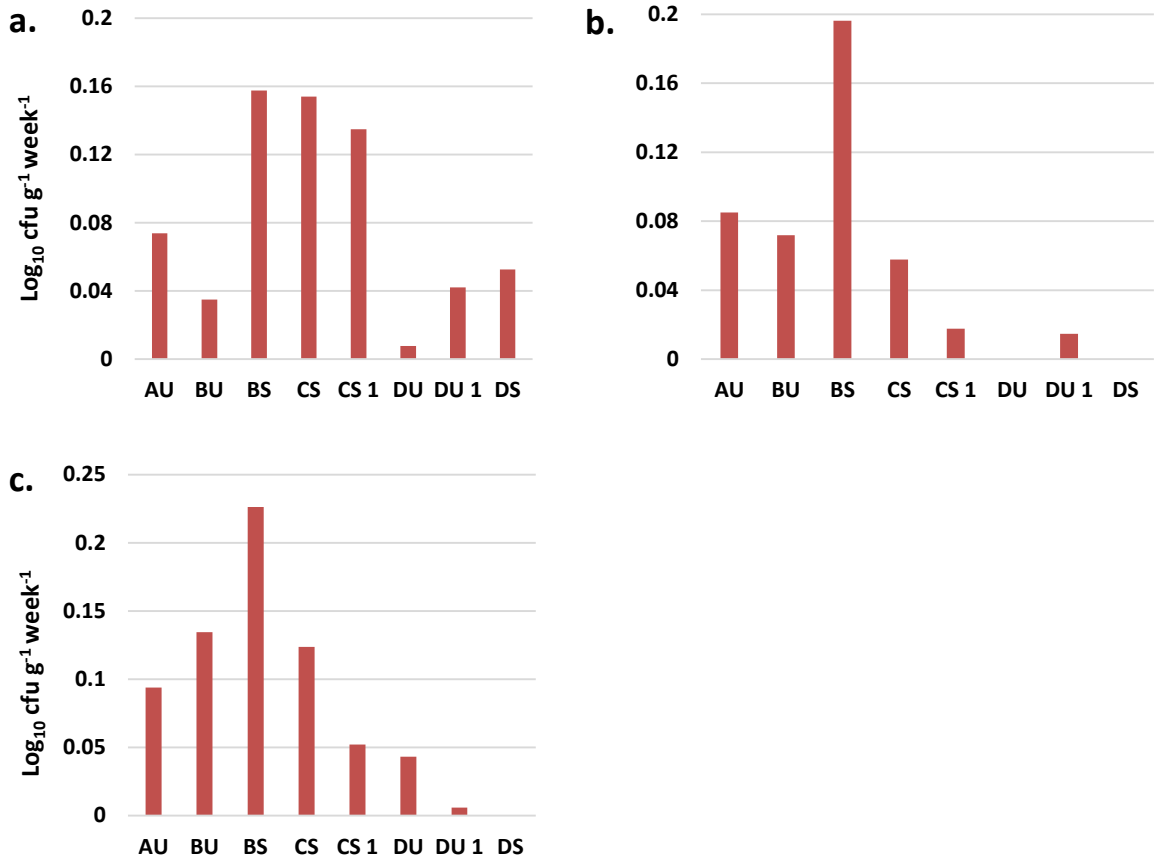

Figure 4- Mean growth rate of microorganisms on butter stored at 5˚C for 24 weeks. (a) TVC, (b) Pseudomonas spp., (c) yeast and moulds.

All three types of microorganisms were growing fastest on BS butter. The lowest mean growth rate of TVC was noted for DU butter, *Pseudomonas spp.* for DU and DS butters and yeast and moulds for DS butter. Industrial butters had on average lower mean growth rates compared to traditional butters: TVC (0.03 and 0.11 respectively), *Pseudomonas spp.* (on average 0.01 and 0.09 respectively) and yeast and moulds (on average 0.02 and 0.13 respectively). Nevertheless, due to a small number of samples a significant difference between growth rates of microorganisms on traditional and industrial butters was only detected for yeast and moulds (t-test, $p<0.05$).

Growth curves of the microorganisms on traditional and industrial butters were presented in Figure 5.

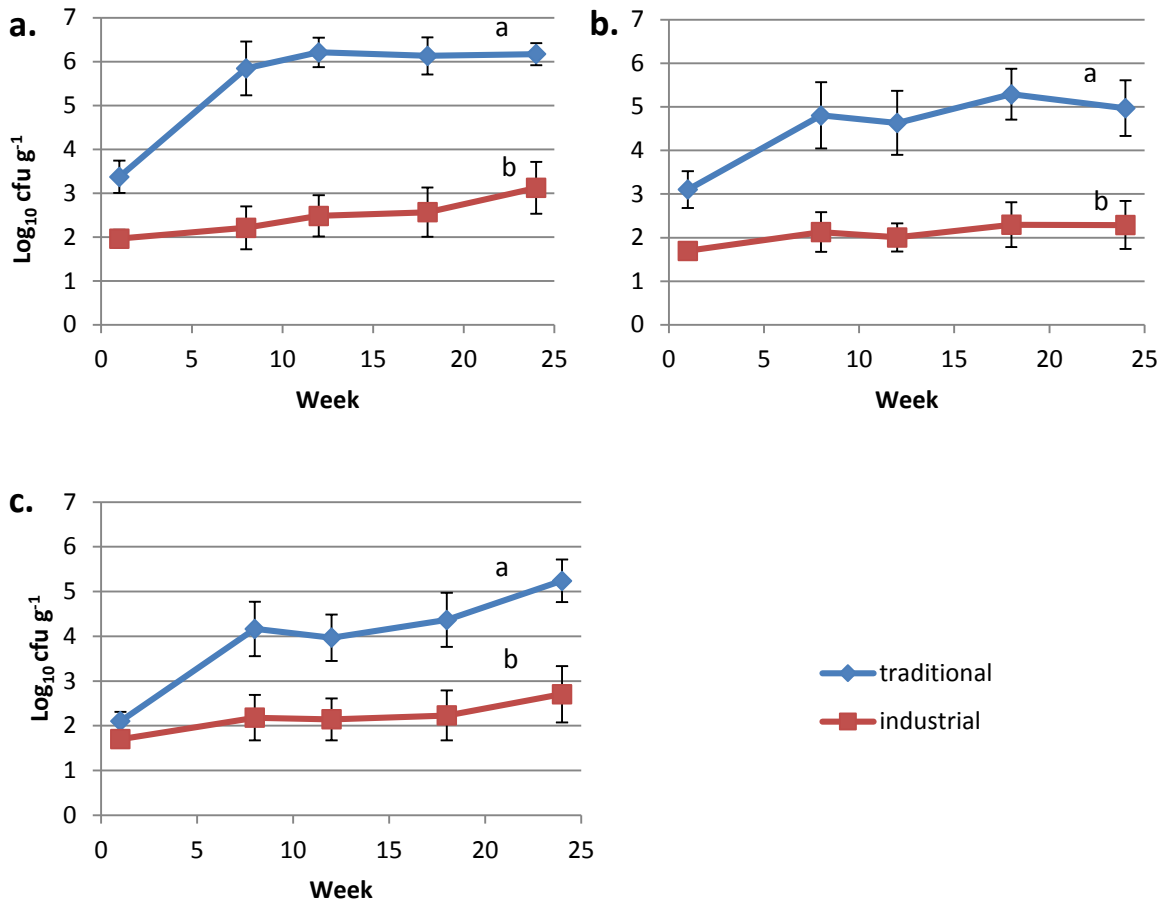

Figure 5- Growth curves of (a) TVC, (b) Pseudomonas spp. and (c) yeast and moulds on traditional and industrial butters stored at 5˚C.. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference (p<0.05 repeated measures ANOVA).

During the whole storage period industrial butters had a significantly lower number of all microorganisms compared to the traditional butters.

There were also significant differences in microorganisms levels between butters from different manufacturers (see Figure 6).

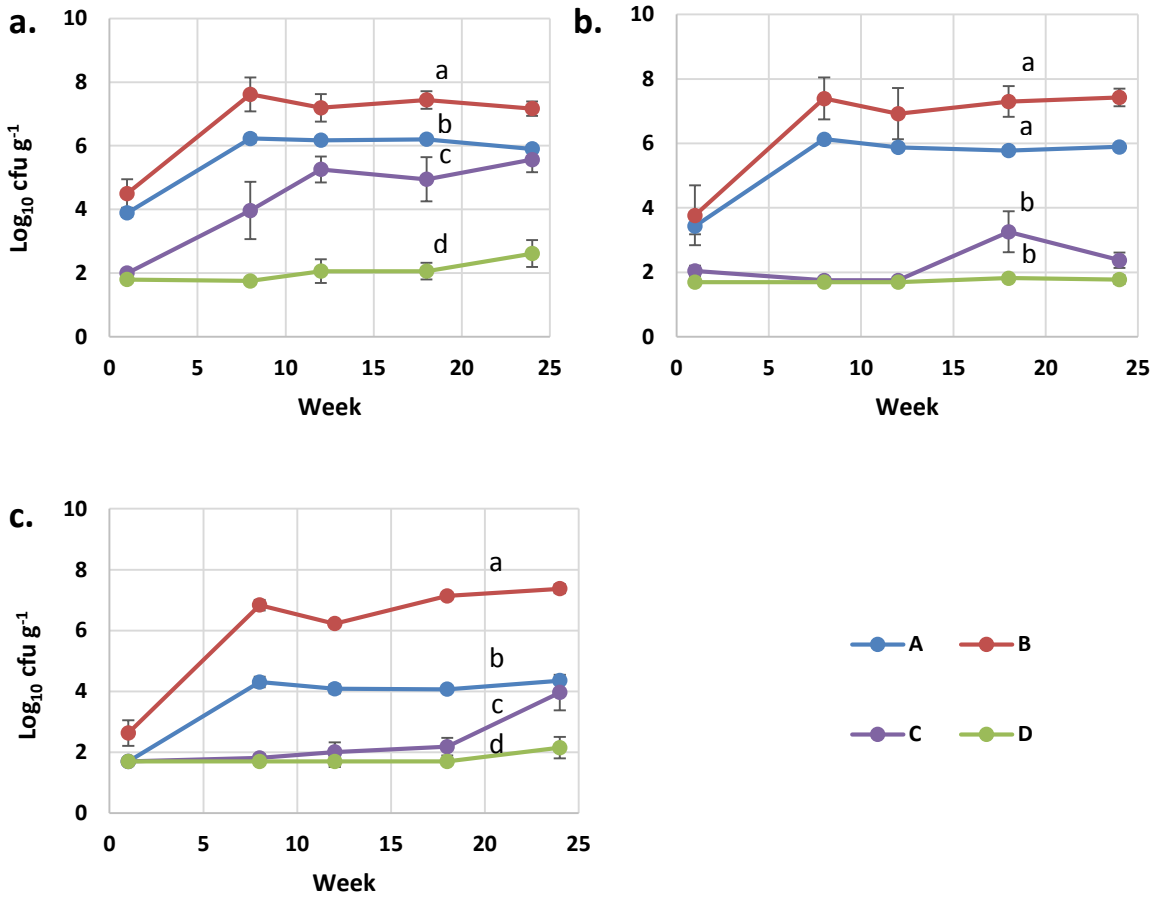

Figure 6- Growth curves of (a) TVC, (b) Pseudomonas spp. and (c) yeast and moulds on butters from different manufacturers. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference ($p<0.05$ repeated measures ANOVA and LSD post-hoc).

The highest microorganism counts over the storage period were found on samples from the manufacturer B, whereas lowest on the samples from the manufacturer D. Samples from the manufacturer C had a significantly higher TVC levels compared to samples from the manufacturer D but very similar *Pseudomonas spp.* and yeast and moulds levels for major part of the storage.

Addition of salt to butter is a factor that should slow down or even eliminate growth of certain microorganisms (Ledenbach and Marshall, 2009). Here we have observed that growth curves of TVC and yeast and moulds on salted and unsalted butter were very similar (see Figure 7 a and c). The only group of microorganisms that presented slightly higher levels on unsalted compared to salted butters was *Pseudomonas spp.*, however given high variability of the results this difference was not significant (Figure 7 c). A potential explanation of this result may be non-uniform salt distribution in the butter (Fernandes, 2009a).

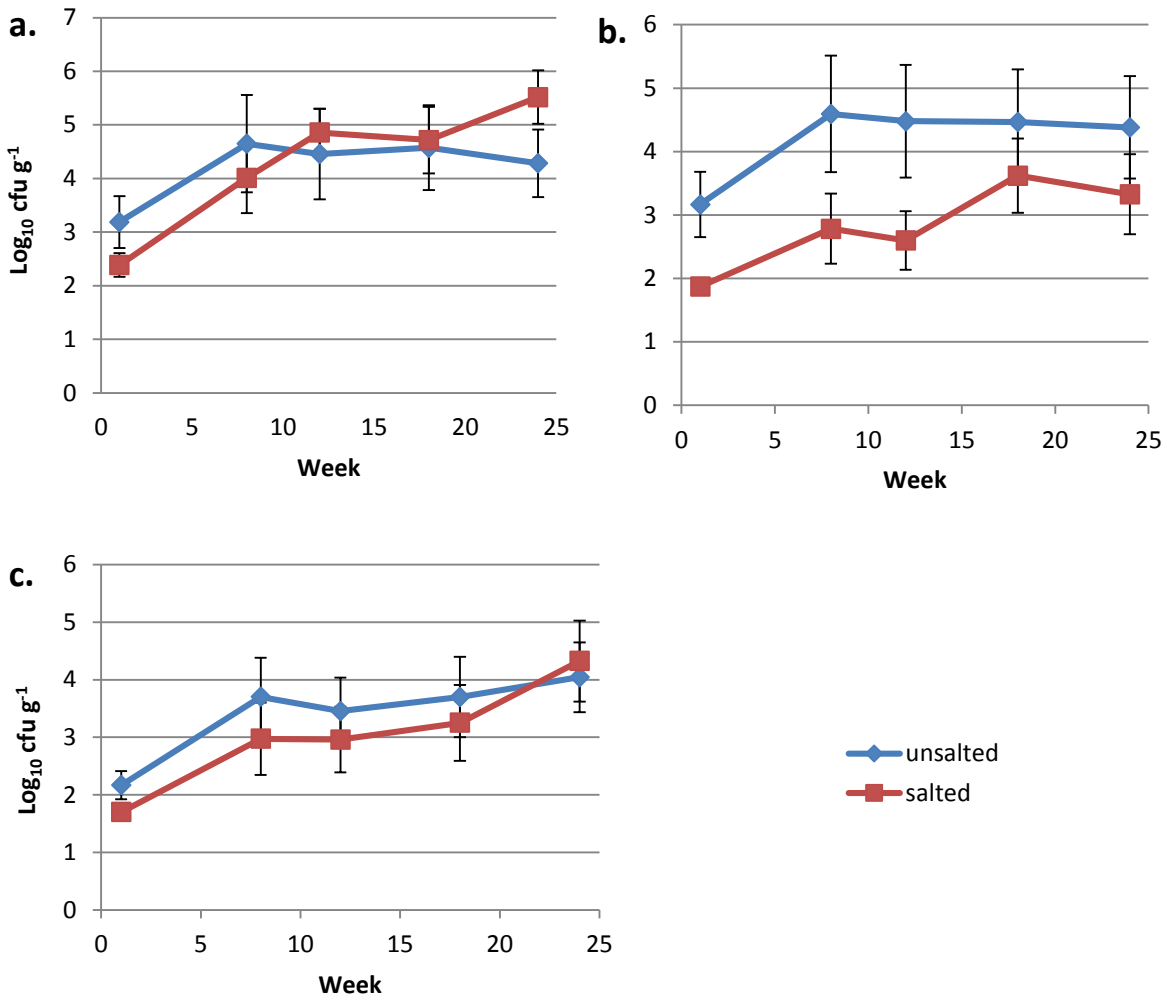

Figure 7- Growth curves of (a) TVC, (b) Pseudomonas spp. and (c) yeast and moulds on unsalted and salted butters stored at 5˚C. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference (p<0.05 repeated measures ANOVA).

Summarising, obtained results suggested that growth of the microorganisms on butter depended on the individual manufacturing process but not on whether the butter was salted or unsalted. Traditional way of butter manufacture seemed to result in butters that were more prone to microbiological spoilage compared to industrially manufactured butters. However, an example of manufacturer C shown that at least in regards to yeast and moulds and *Pseudomonas spp.* this difference may be minimised.

3.3.3 Fat rancidity

Full set of curves showing evolution of peroxide and acid values over 24 week storage at 5˚C for oil separated from each butter sample was given in the supplementary information. Peroxide and acid values for fresh butter oils were summarised in Figure 8.

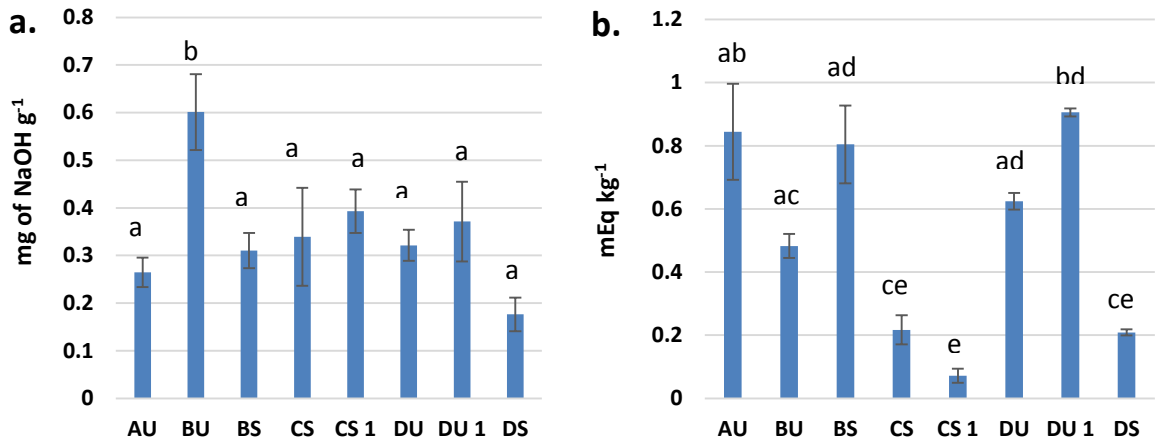

Figure 8- Initial acid (a) and peroxide (b) values of butter oil. Columns correspond to the mean value while error bars to the standard error. Different letters above different columns in the same graph mark a statistically significant difference ($p<0.05$ ANOVA and Tukey post-hoc).

Acid values of butter oils ranged from 0.18 to 0.60 mg of NaOH g^{-1} with lowest for DS and highest for BU sample. With exception of BU all other butter oils were characterised with not statistically significantly different acid values below 0.57 mg of NaOH g^{-1} which was an advised maximum for a butter oil (FAO and WHO, 2007) (converted from cited publication to units used in this work using calculation given in (O'Keefe and Pike, 2014)).

Peroxide values ranged from 0.21 to 0.91 mEq kg^{-1} with highest for DU 1 and lowest for CS 1 sample. Although some sources gave an indication that peroxide values above 0.3 mEq kg^{-1} in butter oil should be accompanied with a detectable off-flavours (Munro et al., 1998), no such off flavour was detected in any of the fresh butters during sensory analysis.

There were statistically significant differences in peroxide values of different butters however these did not seem to depend on whether the butter came from traditional or industrial production. Manufacturer C provided butter samples which oil was characterised with a significantly lower peroxide value compared to oil from butters produced by three other manufacturers (on average 0.14 mEq kg^{-1}, ANOVA and Tukey post-hoc, $p<0.05$). The three remaining manufacturers including industrial butter producer (D) provided butter samples with not significantly different to each other peroxide values of oil (ranging on average from 0.54 to 0.84 mEq kg^{-1}).

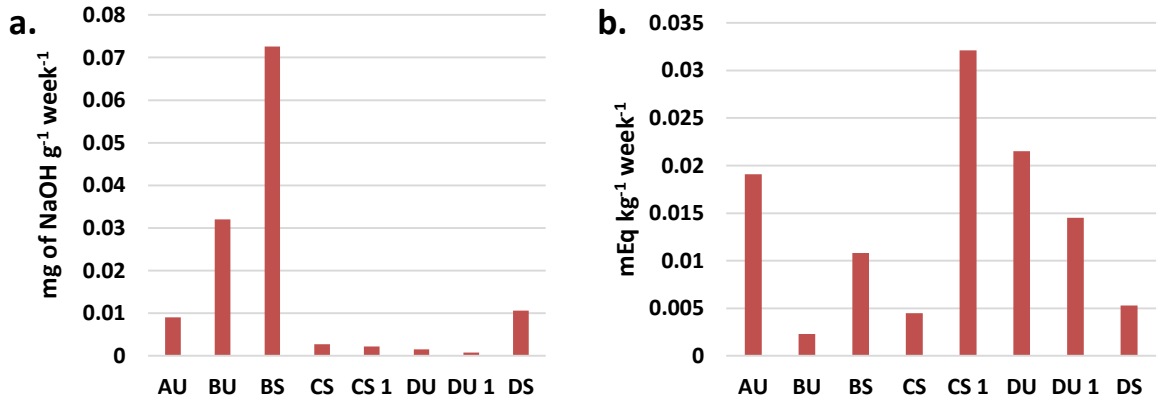

Figure 9- Mean increase rates of acid (a) and peroxide (b) value in oil separated from butter stored at 5˚C for 24 weeks.

The acid value increased fastest in BS and slowest in DU 1 butter oil, whereas peroxide value fastest in CS1 and slowest in BU butter oil. High and low increase rates for peroxide values in both industrial and traditional butter oils were found. Hence it could be concluded that traditional butter making did not impact increase rates of peroxide and acid values. Supporting this conclusion, no significant differences in between evolution of peroxide value over 24 weeks of storage at 5˚C was found in between oils from traditional and industrial butters (see Figure 10 a). Slightly, but significantly higher acid values for oils in stored traditional compared to industrial butters were found. Nevertheless, comparison of acid value evolution in the samples obtained from different manufacturers revealed that only manufacturer B supplied butter samples with more rapidly increasing acid value compared to three other manufacturers (see Figure 11 a). In samples from the manufacturer A peroxide value increased more rapidly compared to samples from manufacturers C and D. However, evolution of peroxide value in oil from butters produced by manufacturers B and C did not significantly differ from one in oil from butters provided by manufacturer D.

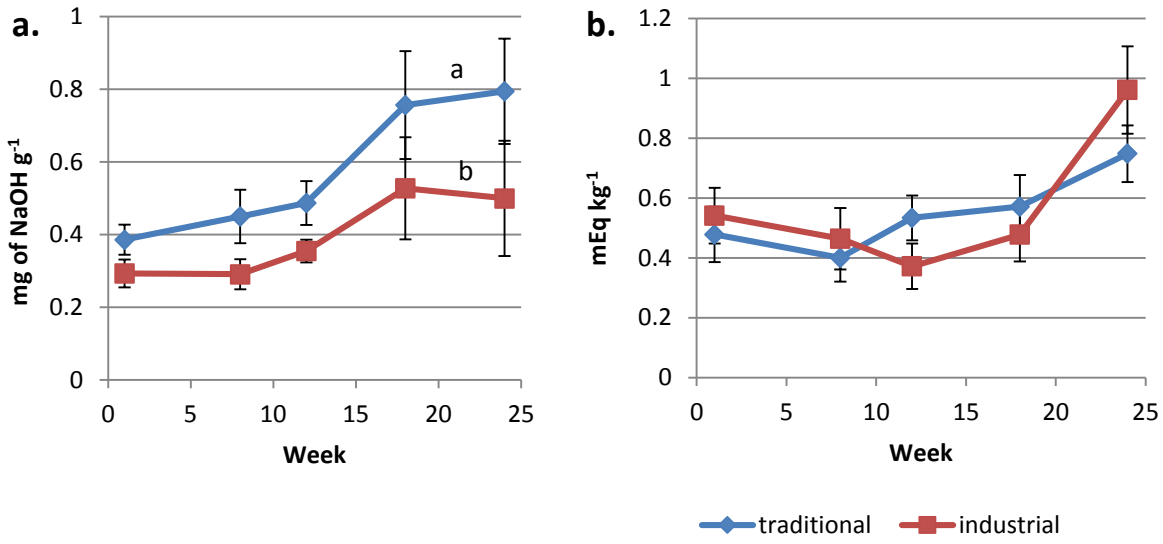

Figure 10- Evolution of acid (a) and peroxide (b) value in oil of traditional and industrial butters stored at 5˚C. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference (p<0.05 repeated measures ANOVA).

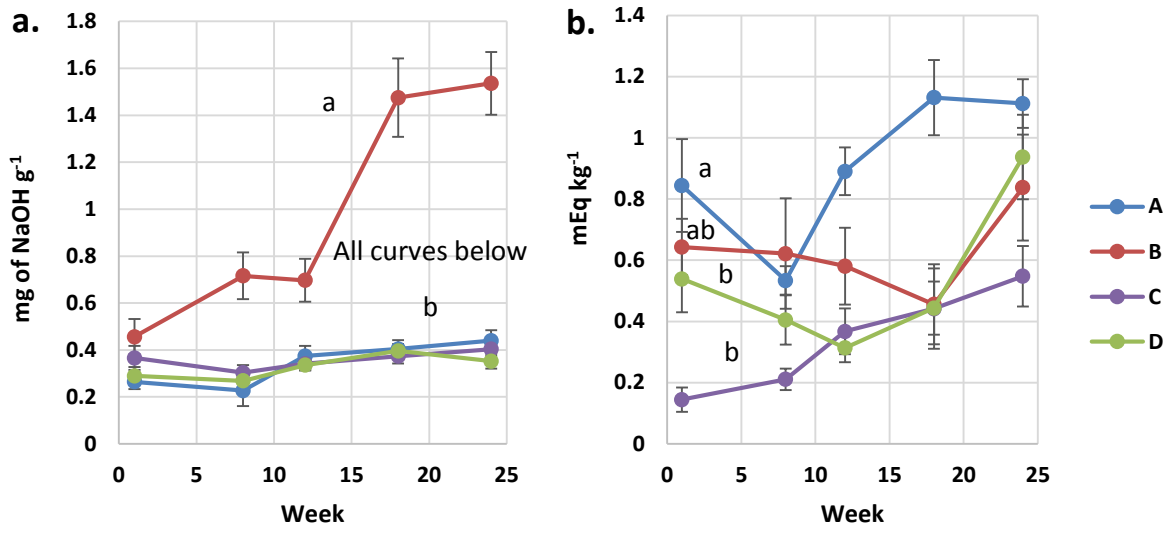

Figure 11- Evolution of (a) acid, (b) peroxide value in oil of butters from different manufacturers. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference (p<0.05 repeated measures ANOVA and LSD post-hoc).

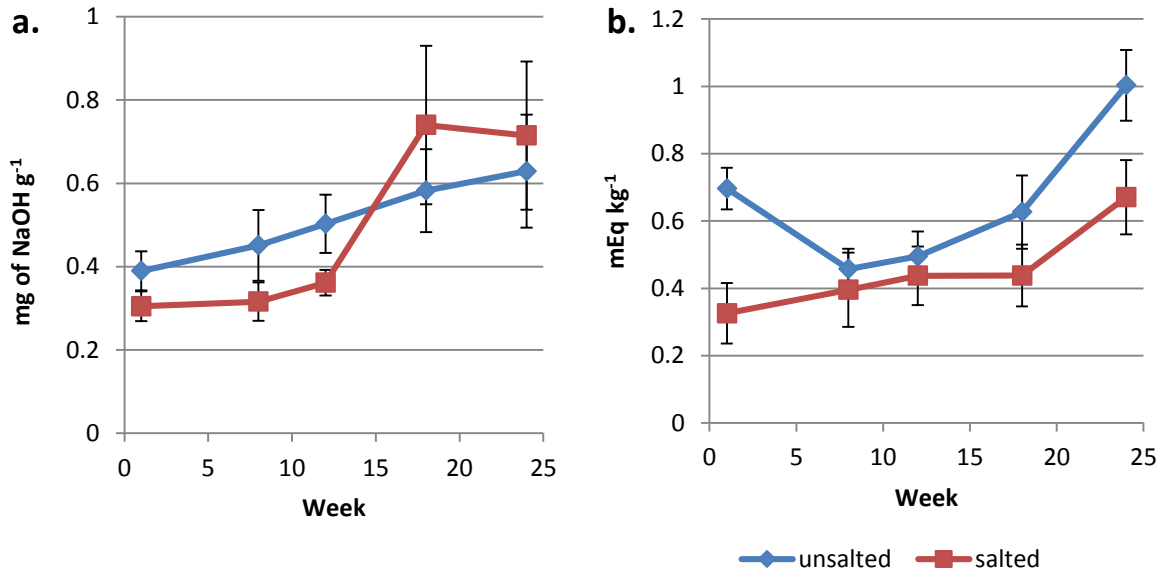

Figure 12- Evolution of (a) acid and (b) peroxide value in oils of unsalted and salted butters stored at 5˚C. Points correspond to the mean microbiological count while error bars to the standard error. Different letters above different lines in the same graph mark a statistically significant difference (p<0.05 repeated measures ANOVA).

Evolution of acid and peroxide values was not significantly different between salted and unsalted butters (see Figure 12).

Summarising, obtained results suggested that the fat rancidity progressed at a very similar rate in traditional and industrial manufactured butters. Additionally initial quality of the butter oil was similar in between two butter types. Addition of salt did not have an impact on the rancidity progress.

3.3.4 Sensory assessment of shelf-life

Appearance and odour of butters during storage at 5˚C for 24 weeks were evaluated. Images of the samples that were frozen at the different stages of the shelf-life were included in Figure 13. Best quality during tested period of time (no off odours and no visible growth of microorganisms for whole

shelf life trial) was noted for butters DU 1, DS, CS and CS 1. Butter DU by week 24 developed a very slight visible microorganism growth but no off odour. Butter AU also had a slight visible growth by the week 24 and additionally slight cheesy off odour. Butters BU and BS were visually and odour-wise not acceptable before week 8 of storage, they had a visible growth of colonies and a distinct cheesy off-odour.

Where found, visible microorganism growth was only present on the surface and not inside of the butter blocks (see Figure 13).

All the manufacturers judged the shelf life of offered butters correctly as neither of the samples spoiled before termination of the stated shelf life.

Spoilage was accompanied by TVC counts of 1.98 to 8.80 $\log_{10}$ cfu g^{-1}, *Pseudomonas spp*. counts of under the limit of detection up to 8.84 $\log_{10}$ cfu g^{-1} and yeast and moulds counts of 2.89 to 7.12 $\log_{10}$ cfu g^{-1} as well as peroxide values of 0.22 to 1.11 mEq kg^{-1} and acid values of 0.44 to 0.92 mg of NaOH g^{-1}. Large range of these values indicated that factors other than fat rancidity development and growth of the microorganisms were also contributing to the butter spoilage. The fact that the growth of microorganisms started to be visible at much different concentrations in different samples could be also a consequence of sampling and visible ability of microorganisms to grow only on the surface of the butter.

Another important factor for longevity of the butter is water dispersion (Fernandes, 2009a). Results of water dispersion test were described in section 3.4.

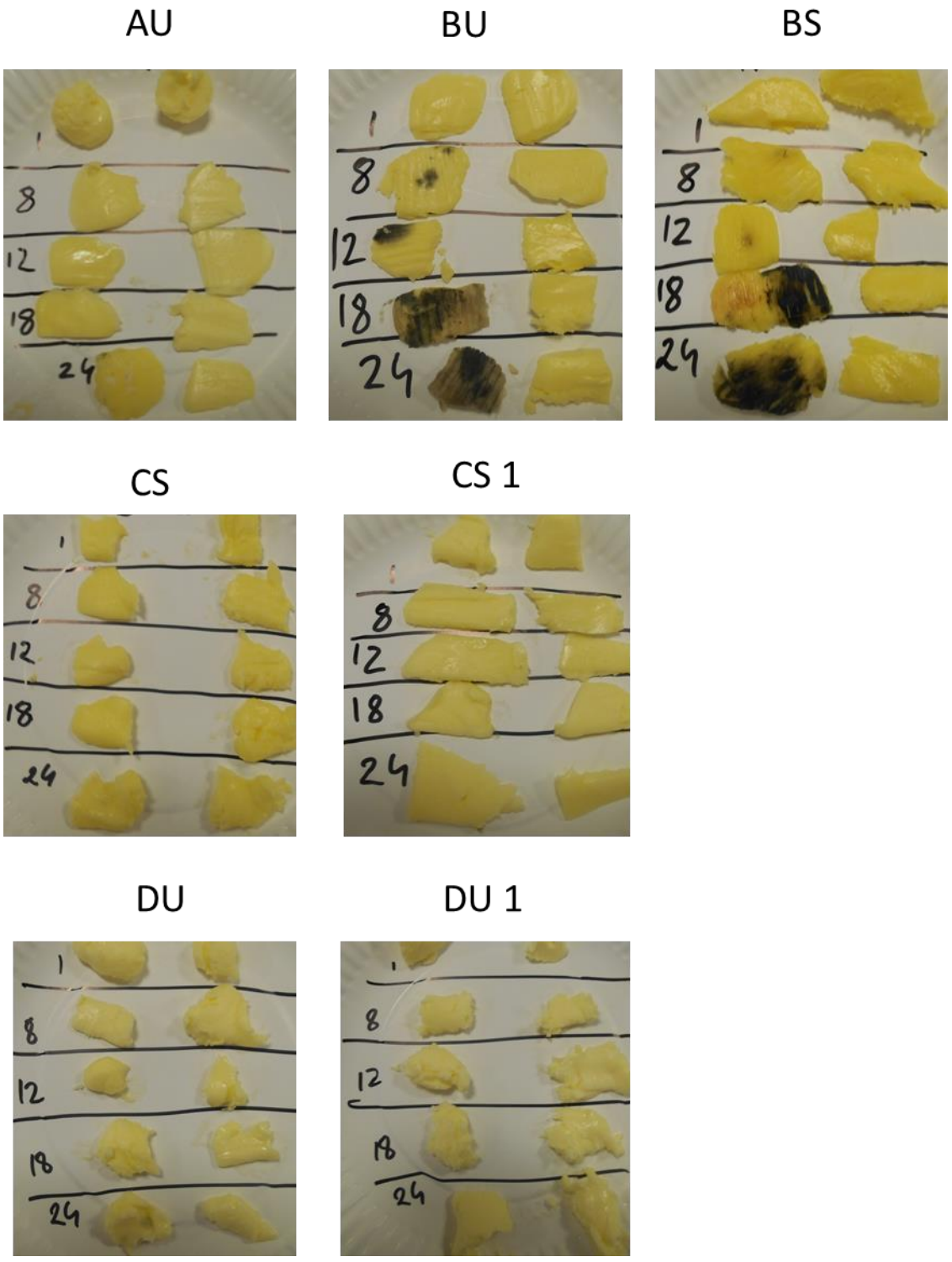

Figure 13- Appearance of the butters during shelf life trial, samples on the left side of each picture represent butter surface and on the right- butter cross section fragments. Numbers correspond to the week of the storage. Results for sample DS were not given as they were very similar to sample DU 1.

3.4 Water dispersion in butter

The results of water dispersion analysis were presented in Figure 14. All traditional butters with exception of CS 1 contained large droplets of water (larger than 3 mm to above 1 cm) that covered large surface part of the indicator paper (more than 10%). Butter BS was characterised with the worst water dispersion in this group and AU best. Industrial butters and CS 1, according to the scale given by the manufacturer of the indicator papers used in this study, had an acceptable water dispersion with small droplets of water (1-3 mm) covering up to 5% of the paper's surface.

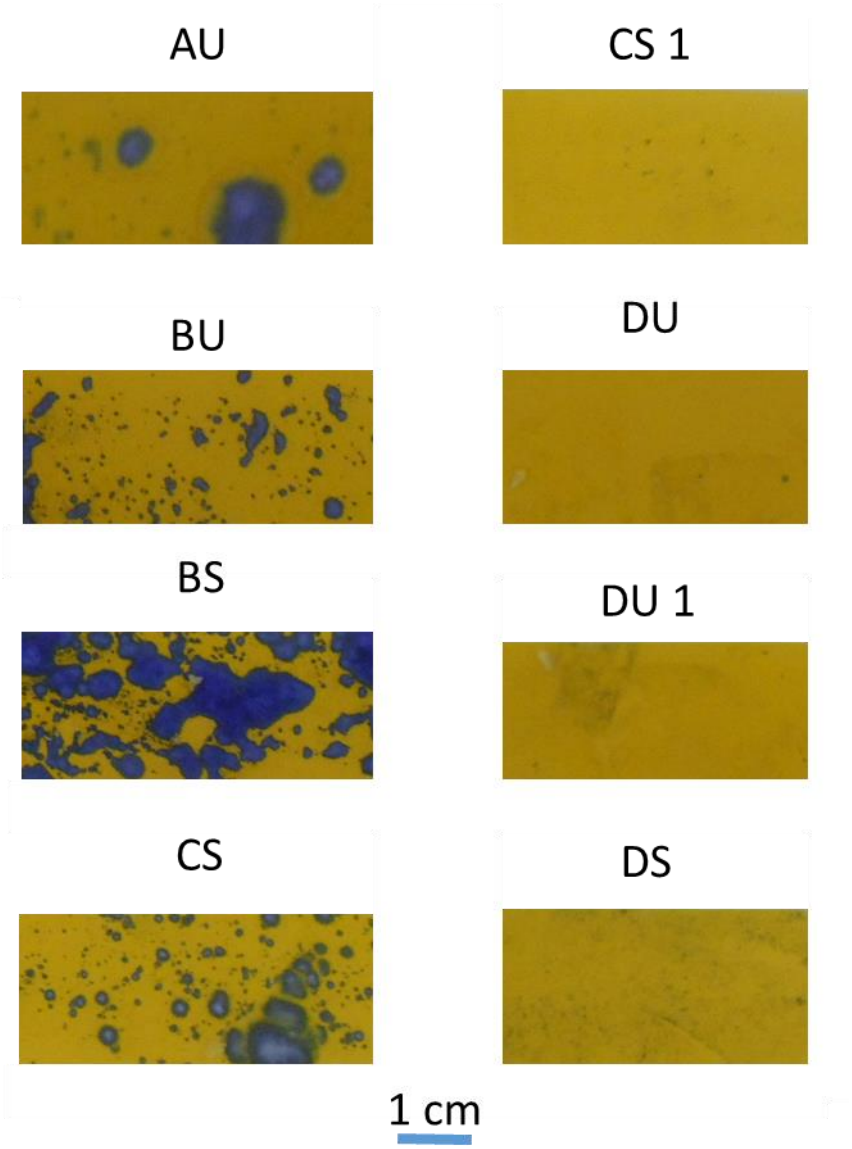

Figure 14- Water dispersion in butter

3.5 Chemical assessment of traditonal and industrial butters

Table 4- Chemical composition and water activity of studied butters mean values ± standard errors. Different letters in different rows of a same column mark a statistically significant difference ($p<0.05$ ANOVA and Tukey post-hoc).

Butter sample	Moisture %	Fat %	Water activity
AU	12.6 ± 0.1 ab	86.4 ± 0.2 a	0.96 ± 0.00 a
BU	12.2 ± 0.2 a	86.5 ± 0.2 a	0.98 ± 0.00 a
BS	13.6 ± 1.0 acd	85.4 ± 0.2 ab	0.82 ± 0.02 c
CS	12.6 ± 0.3 ad	86.8 ± 0.4 ab	0.73 ± 0.00 b
CS 1	13.6 ± 0.4 acd	85.6 ± 0.5 b	0.73 ± 0.01 b
DU	14.3 ± 0.3 bce	84.7 ± 0.2 ab	0.97 ± 0.00 a
DU 1	15.9 ± 0.5 e	83.9 ± 0.3 c	0.98 ± 0.00 a
DS	14.4 ± 0.1 bde	83.1 ± 0.3 c	0.71 ± 0.01 b

There were significant differences in moisture and fat content between the butters (see Table 4). Highest moisture content was found in DU 1 while lowest in BU butter. Butter CS was characterised with a highest amount of fat, while butter DS with lowest. Products from traditional butter manufacturers all contained similar amount of fat and moisture (ANOVA and Tukey post-hoc $p>0.05$). Further data analysis indicated that industrially made butters contained significantly (t-test, $p<0.05$) more moisture (on average 15.0 %) and less fat (on average 84.3 %) compared to traditional butters (on average 13.0 and 86.5 % respectively). This outcome is not surprising since, within the industrial process, manufacturer was able to monitor and control the amount of water in the butter, while no similar control was observed in the traditional production.

The water activity differed in between butters (see Table 4). This difference was depending on a salt content in each butter. Butters with 2 % salt content had a water activity ranging from 0.71 to 0.73 while unsalted butters from 0.96 to 0.98. Butter with 0.5 % salt content had water activity of 0.82. All salted butters had water activity on a level preventing growth of bacteria, but allowing growth of yeasts and moulds (Fontana, 2007).

4. Conclusion

The traditional and industrial butter manufacture differed considerably. The traditional butter was made using batch churning process while industrial butter using continuous process. Both these processes were well described by Wilbey (2002). Additionally traditional butter manufacturing involved in most of cases (four out of five butters) hand forming and packaging of the butter. Due to the production scale the industrial butter was made based on milk from many different suppliers while traditional manufacturers used predominantly milk from their own cows (in this study two out of three manufacturers did so).

This study found that the traditional butters may be indeed preferred by the consumers to industrially produced, high quality butters. This hypothesis was confirmed based on unsalted butters. Nevertheless, sensory quality of the industrial butter could be considerably improved by addition of lactic acid and diacetyl, matching high sensory scores obtained by the traditional butter.

Salted butters were assessed by the sensory panel equally well regardless of whether they were industrially or traditionally produced. The sensory acceptance of salted butters seemed to improve with increase of the salt level.

Sensory evaluation of the traditional butters also indicated that appearance of these products may be compromised by a poor water dispersion. The water dispersion was generally worse for traditional compared to industrial butters (in four out of five cases). This factor could influence a growth of the microorganism. Microorganism growth indeed tended to be faster on traditional compared to the industrial butters. Faster growth of microorganisms and higher initial microbiological load found on some of the traditional butter samples could result in a shorter shelf life of these products. Nevertheless this was not the case for all the samples. Only two out of five tested traditional butters had a shorter shelf life (evaluated based on sensory acceptance) compared to the industrially produced butters. Both of these butters were produced by the same manufacturer. One of these butters carried higher microbiological counts compared to all the other analysed butters. Another one was characterised by a very poor water dispersion and more rapid increase of microorganisms population over the storage period compared to all other analysed butters. It is hence proposed that the manufacturer could prolong a shelf life of the butter by the improvement of the water dispersion and reduction of the initial microbiological contamination. Poor water dispersion may be a consequence of temperature during churning being too high. At a churning temperature higher than 13˚C a high amount of butter fat is liquid and kneading does not allow for working the moisture into the butter very well (Nielsen, 1971). High microbiological counts in a sweet cream butter right after production may be a consequence of: 1. high microbiological counts in cream, 2. butter and cream handling during and post production and 3. insufficient removal of the buttermilk. For an adequate removal of the buttermilk butter grains need to be washed 2-3 times with drinking water of good microbiological quality e.g. pasteurised and in a volume corresponding to the volume of cream used for butter production (Berthold-Pluta et al., 2013; Nutrivitality). Washing improves microbiological quality and shelf life stability of the butter by removal of residual buttermilk together with the microbes and reduction of nutritious proteins and lactose, which would allow these microbes to grow (Berthold-Pluta et al., 2013; Spreer, 1998). Washing may also be used to control temperature of butter grains prior to kneading (important for appropriate water dispersion) and is known to limit lipolysis in the butter (Berthold-Pluta et al., 2013). Nevertheless, some authors argue that washing reduces flavour creating compounds, resulting in lower sensory desirability (Spreer, 1998).

Quality of fat in fresh and stored traditional butters was very similar to industrial butters evaluated in this study. The only exception were butters from traditional manufacturer B. In these butters acid values increased more rapidly than in others.

Summarising, this study confirmed consumer perception that traditional butters may be characterised by a higher sensory desirability compared to the industrial butters. It did not ambiguously confirm claim that the traditional butters have a shorter shelf life than industrial butters. This presumption held true only for butters from one out of three traditional manufacturers. Further insight into individual processes of this manufacturer could help improve shelf life of the offered butters.

Acknowledgment

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