Sensory quality and shelf life of locally produced British butters compared to large-scale, industrially produced butters

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Sensory quality and shelf life of locally produced British butters compared to large-scale, industrially produced butters

Abstract

Purpose

The purpose of this pilot-scale study was to compare the quality of traditionally manufactured butters from local, small British producers with the quality of industrially-produced butters.

Design/methodology/approach

Butter samples were obtained after supervised site inspections of three traditional butter manufacturers and one large scale butter producer. The samples were subject to initial microbiological, chemical and sensory testing, followed by a refrigerated shelf life study over 24 weeks.

Findings

Traditional butters matched or exceeded the sensory quality of industrial butters, but spoilage microorganisms tended to grow faster on traditional butters. This seemed to be related to poorer water droplet dispersion in the manufacture of some of the traditionally-made butters. Visible mould appeared on two of the traditional butters after 8 weeks, but this occurred well after the nominal ‘best before’ date.

Originality

Prolonged lockdowns due to the current COVID-19 pandemic pose a threat to the food supply chain, and food produced by local manufacturers may become increasingly important. However, are foods produced by local small-scale manufacturers of a quality comparable to that produced using large scale production facilities? To the best of our knowledge, there is no comparative study of the quality and shelf life of traditionally-produced and industrially-produced butters. This work presents such a comparison together with an outline of how the process of traditional butter-making differs from commercial production in Britain.

Keywords: Traditional butter, hand-made butter, local butter production, British butter, quality of butter, shelf life of butter
Introduction

The ability of the food supply chain to deliver food to consumers in a timely manner is under threat from the prolonged lockdowns in response to the current COVID-19 pandemic (Singh et al., 2020). Consequently, food produced by local manufacturers is gaining importance. However, are local manufacturers, using small scale traditional equipment, able to match the quality of foods made using large scale production facilities? This question is especially applicable to foods such as butter, where the production process requires many steps.

UK consumers perceive foods sold locally by small producers e.g. farmer’s markets, to be fresher, tastier and possibly of higher quality than foods supplied to retail outlets by large manufacturers (McEachern et al., 2010; Spiller, 2012). Farmers’ markets offer a range of artisan foods that are uncommon in supermarkets, and consumers place a high value on the traditional skills required to make such products (Autio et al., 2013).

Despite current consumer interest in farmer’s markets, artisan, and locally-sourced foods; there is limited information on the quality and shelf life of such products. Small food businesses struggle with implementation of food hygiene and quality systems (Department for Business Innovation & Skills, 2013). A recent study carried out in Wales identified issues which hamper the certification of micro and small food businesses with food safety schemes (Evans and Taylor, 2019). Certification seems to impact positively upon the functioning of the safety systems in food establishments (Trafialek and Kolanowski, 2017) but it cannot be ruled out that practices increase the risk without performing a review, and gathering information on the quality and shelf life of offered products.

Hand-made butter is an artisan food. Most opinions and small surveys presented in the world wide web state the sensory quality of hand-made butters to be superior to retail brands, Nevertheless, there are no scientific reports in the peer-reviewed literature comparing hand-made butter with industrially-produced butter in terms of sensory quality, or chemical compounds impacting on flavour and odour.

There is no official compilation of data on hand-made butter consumption or sales in the UK. Several farm shops have websites to promote their products. These sites indicate farmers make their hand-made butters on the farm using milk from their own herds. Some sites emphasise their hand-made butter is made using traditional methods. Nevertheless, what is meant by “traditional” is not explained. Without details of the process, it is difficult to assess the impact of such practices on the shelf life of the butter.

The main factors which will influence the shelf life of butter and its quality include; the method of cream pasteurisation, the hygiene and control of the production, as well as the efficiency of the buttermilk removal and its dispersion within the butter blocks.

The removal of buttermilk during the butter production process leaves butter with a low microbiological count and limited nutrients for microbial growth. The buttermilk that remains is dispersed in the fat phase of the butter block as fine droplets. This compartmentation of water and nutrients acts to further limit microbial growth (Budkhar et al., 2014; Berthold-Pluta et al., 2013; Fernandes, 2009; Adams and Moss, 2008; Spreer, 1998). When microbial spoilage of butter does occur, it is commonly due to contamination with bacteria of genus Pseudomonas, as well as some yeasts and moulds that are able to survive and grow at low temperatures (Budkhar et al., 2014).

Unsalted butter contains a minimum of 82% butterfat, and off-odours arising during storage from lipid oxidation and/or lipid hydrolysis by heat-resistant microbial lipases, are the main reason for the termination of butter’s shelf life (Munro et al., 1998; Champagne et al., 1994). Sensitive chemical tests, utilising instrumental (Fourier transform infrared, spectrophotometry, chromatography, nuclear magnetic resonance) as well as titrimetric methods are available to monitor the progress towards oxidative and hydrolytic rancidity (Shahidi and Zhong, 2005; Wiking et al., 2017).

Development of fat rancidity and microbiological spoilage of butter will be reduced by the effective removal of buttermilk and sufficient dispersion of buttermilk droplets within the butter block (Budkhar
et al., 2014; Fernandes, 2009). Large droplets of buttermilk allow microbes to thrive (Berthold-Pluta et al., 2013; Spreer, 1998). Additionally, water is an environment for enzymatic and chemical reactions; thus enzyme catalysed fat rancidity is only possible on the interface of fat and water, while oxidation-induced rancidity goes faster in products with reduced water content (Beuchat, 1978; Feiner, 2006). Therefore, alongside microbiological and chemical parameters, water dispersion level is one of the factors of interest in evaluating the shelf life of butter.

This pilot-scale study aimed to:

1. Establish what the term “traditional butter production” really means and whether it differs considerably from industrial production.
2. Conduct a sensory comparison of butters
3. Use headspace (HS) solid-phase microextraction (SPME) coupled with gas chromatography-mass spectrometry (GC-MS) to compare volatile odour and flavour compounds
4. Evaluate shelf life influencing parameters—microbiological, chemical and water dispersion analysis of the traditional butter and compare it to high quality butter available from bulk retail.

This study also sought to provide the producers of hand-made butters with insights into their manufacturing practices.

Materials and methods

Visits to butter manufacturers in order to compare the traditional and industrial practices and define the meaning behind the traditional butter manufacturing

One industrial and three traditional butter manufacturers were visited in the course of the project. During these visits, the process of butter-making was observed and documented in writing and on photographs. One traditional butter manufacturer did not permit photography. Hosts answered questions regarding the process according to our structured interview. The questions and answers were recorded and are summarised in the results section.

Collected samples

Five traditional butter samples from three manufacturers (A, B and C) and three industrial butter samples from a single manufacturer (D) were collected. Different types of cream were applied in the production of traditional butters. Samples included unsalted and salted butters. One of the industrial butter samples contained additives with the purpose of giving a sensory impression of butter made from a cultured cream. Butter characteristics are summarised in Table I.

To ensure the representativeness of collected butter samples, the final results were shared with the butter manufacturers prior to publication. In addition, two of the manufacturers (C and D) have shown us during the visits results of microbiological and chemical analyses for different batches of their products.

Sensory quality of the butters

Butter samples were cut with a roller-shaped template, placed in a coded plastic container with a lid, and stored for 24 h at 12°C prior to sensory analysis according to ISO 22935-2:2009.

Fifteen untrained volunteers evaluated butter using the 5 point hedonic scale shown below for: odour, appearance, flavour and consistency.

1- dislike very much
2- dislike a little
3- not sure
4- like a little
5- like very much
An overall score for each butter was calculated by multiplying the points given to each assessed trait by an assigned importance coefficient and summing all the results in a single score. The assigned importance coefficients for individual traits were based on a previously published work on the sensory evaluation of butter (Czechowska-Liszka, 2005). The importance coefficients were: odour- 0.3, appearance- 0.1, flavour- 0.4, and consistency- 0.2.

The volunteers also rated butter samples from the one preferred the most to the one preferred the least. A same score to multiple butter samples was given if they were of similar desirability.

Unsalted and salted butters were evaluated separately, starting with unsalted butters.

**HS-SPME-GC-MS identification of the odour and flavour compounds**

2.5 g butter samples were melted at 45 °C and transferred to 20 mL headspace vials. The vials were capped, transferred to a heating block, and allowed to equilibrate for 60 min at 36 °C. Next, a 1 cm 50/30 μm Divinylbenzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PDMS) SPME fibre (Sigma-Aldrich Company Ltd., Dorset, England) was injected into the headspace and allowed to extract volatile organic compounds (VOCs) for 60 min at 36 °C.

After extraction, VOCs were measured using a Shimadzu QP-2010 Gas Chromatograph Mass Spectrometer running Shimadzu LabSolutions GCMS Version 4.11 SU2 software (Shimadzu UK Limited, Milton Keynes, UK). Volatiles were desorbed from the fibre into the injection port equipped with Agilent Crosslab Ultra Inert SPME inlet liner (Agilent Technologies, Inc., Santa Clara, CA) at 270 °C for 1 min in splitless mode. Compounds were separated with an Agilent J&W DB-1MS UI GC Column 30 m × 0.25 mm i.d. × 0.25 μm film thickness (Agilent Technologies, Inc.) using helium as the carrier gas at 1 mL·min⁻¹. The oven temperature was programmed to increase from 40 °C (held for 1 min) to 270 °C at 10 °C·min⁻¹, then held at 270 °C for 10 min.

Mass spectra were recorded over the time period 1.2 to 34 min, in electron-impact (EI) mode at 70 eV, in the mass to charge ratio range (m/z) 35-500. The transfer line and ion source temperatures were maintained at 270 °C and 200 °C, respectively. Kovats retention indices were calculated from separate SPME experiments under the same instrumental conditions with a range of n-alkanes from C5 - C30 (Sigma-Aldrich Company Ltd., Dorset, England). Compounds were identified by retention index and by mass spectral comparison with the NIST/EPA/NIH 2011 Mass Spectral Library.

The relative amounts of each compound in the butter samples were determined by selecting a unique ion from the mass spectrum (the quantification ion) and calculating the quantification ion peak area.

Four samples, one from each manufacturer, were analysed for VOCs, namely: AU, BU, CS and DU1.

The 10 most abundant compounds (by quant ion peak area) arising from the butter samples, together with 4 compounds known to influence butter odour and flavour, are presented in the results section.

This analysis was only qualitative and has been performed on one replicate per sample.

**Shelf life of the butters**

Butter samples were prepared for microbiological analyses according to ISO 6887-1:1999. The diluent was kept in the room temperature and was enriched with 0.9% Tween 80.

Fresh butter samples were analysed for initial microbiological contamination. Studied microorganisms included: aerobic colony count (ACC), Enterobacteriaceae, Pseudomonas spp. and yeast and moulds.

With the exception of Enterobacteriaceae, which were enumerated only in fresh samples, analyses were also carried out for samples stored at 5°C for 8, 12, 18 and 24 weeks. All sample-replicates were taken from individual blocks of butters. Subsample of fresh butter from the commercial manufacturer was
taken from a 25 kg block at the production plant. Remaining samples were taken from the individually packed 200 g portions of butter.

Enterobacteriaceae and ACC were enumerated according to ISO 21528-2:2004 and ISO 4833-2:2013 methods, respectively. Enumeration of *Pseudomonas* spp. and yeast and moulds was carried out on Cetrimide-Fucidin-Cephalosporin *Pseudomonas* agar incubated for 48 h. Yeast and moulds were cultured on Rose Bengal Chloramphenicol agar incubated for 120 hours, respectively. Both *Pseudomonas* spp. and yeast and moulds were introduced on the media using spread-plate method and cultured at 25°C. Limit of detection (LOD) was at a level of 1 log cfu g⁻¹ for Enterobacteriaceae and 2 log cfu g⁻¹ for all remaining microorganisms. To include microbial counts <LOD into statistics one of the commonly used methods was applied, namely such counts were substituted with Statistical analyses and presentation of data below LOD used 50% LOD value counted based on of raw counts (Garcés-Vega and Marks, 2014).

All microbiological media were purchased from Oxoid (Altrincham, UK).

For the determination of peroxide and acid values, butter oil was separated from butter (melted at 50°C) by centrifugation in 1.5 ml tubes (Eppendorf, Hamburg, DE) at 14 500 rpm for 5 min in a MiniSpin Plus centrifuge fitted with a F-45-12-11 rotor. Oil from 2-3 Eppendorf tubes was combined in a single, pre-weighed conical flask. Samples were then weighed and analysed as described below.

Peroxide and acid values for fresh and stored samples were determined according to ISO 3960:2007 and ISO 660:2009 standards respectively.

Fresh butter was up to 1 week old collected during visits and stored in frozen conditions to the day of analysis.

All microbiological and fat rancidity analyses were performed in triplicate.

The water dispersion analysis was performed using a commercial indicator paper (Dysperwody, Lablacta, Olsztyn, PL) according to the manufacturer’s instructions. Butter samples were kept for 24 h at 13°C prior to the evaluation (as recommended by International Dairy Federation 112A (1989) standard) and then cut with a thin knife. The indicator paper was attached to a freshly uncovered butter surface, gently pressed and removed to read results. Results were assessed qualitatively, based on the size and number of visible stains and comparing results between samples. Samples were ranked according to the qualitative assessment of the water dispersion from 1 - the worst best to 8 - the best worst. Then the correlation analyses between water dispersion and mean growth rates for microorganisms as well as mean increases of peroxide and acid values through the 24 weeks of storage with ranks were performed.

**Statistical analyses**

Statistical data analyses were performed by means of IBM SPSS Statistics version 21 (parametric statistics), Past (nonparametric tests) and Microsoft Excel (regression analysis and descriptive statistics) assuming a significance level of α=0.05. Relevant assessments are mentioned in the text along with analysed data.

Pearson’s R coefficient values were evaluated based on the guidance given by Gronowska-Senger and Arauz (2013).
Results

Review of butter manufacturing processes

The information obtained through the structured interview and visiting butter manufacturing premises is summarised in Table II.

The most notable differences between traditional and industrial butter production were: the production set-up, the way the buttermilk was drained, and the method of forming single portions.

The industrial butter manufacturer used a continuous production set-up, while all traditional manufacturers used batch processing; which meant filling, emptying and sanitising the churner in each single production run.

In the industrially-produced butter filters on the walls of the churner and subsequent two compartments of the system drained the buttermilk, without rinsing the obtained butter granules with water. On the other hand, all traditionally-produced butters were washed with water, and the buttermilk and water were removed by gravity, through a valve at the bottom of the churner.

Forming was performed by the extrusion of large butter blocks in the industrial plant, whereas traditional manufacturers formed their butters either by hand (AU, BU, BS) or applying semi- (CS) or full-automation (CS1). Scotch hands for butter forming were used by two out of three traditional butter manufacturers (A and B).

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 for industrial and traditional processes (about 15°C), whereas cream storage temperature and time depended on the individual manufacturers. The time required for production of butter also varied between individual butter manufacturers. The industrial butter producer claimed their continuous system reduced the production time 2 to 6-fold compared to batch processing.

Sensory quality of the butters

The results of sensory evaluation are summarised in Figure 1.

In the group of unsalted butters, traditional butter BU received higher scores for odour and overall quality than the remaining butters, and scored significantly higher in these attributes than butters AU (only flavour) and DU (repeated measures Friedman’s ANOVA, Wilcoxon’s test with Bonferroni correction post-hoc, p<0.05). This butter was also most favourably perceived by the panellists (8 out of 15 participants liked it the most) followed by AU (4 nominations), DU1 (3 nominations) and DU (2 nominations). An industrially-made butter DU1 was given a slightly, but not significantly lower score than BU. Comparing DU1 with DU; the addition of lactic acid and diacetyl increased odour, flavour and overall scores, but these increases were not significant.

No statistically significant differences in any of the assessed sensory quality traits, with the exception of appearance, where the traditional BS butter scored significantly lower than others, were noted in the group of salted butters. The panellists nominated favourite butters in the following order: DS (7 nominations), CS1 (6 nominations), CS (3 nominations) and BS (2 nominations).

Among salted and unsalted butters some panellists have nominated more than one butter as the one they liked the most, hence the sum of the nominations exceeds the number of panellists.
**Flavour and odour compounds**

The GC-MS analysis detected over 130 volatile compounds over the butter samples; and Figure 2 shows fourteen selected compounds. The ten most abundant VOCs were: acetone, diacetyl, 2-butanone, trichloromethane, acetic acid, pentanal, toluene, hexanal, butanoic acid, and 2-heptanone. The four other compounds: acetaldehyde, delta-hexalactone, delta-octalactone, and delta-decalactone, were considered important contributors to butter’s odour and flavour based on literature data. The levels of these compounds varied in analysed butters. For example, the traditional whey cream butter (AU) contained less lactones and more toluene than other butters, and diacetyl was very prominent in the industrial butter sample, DU1.

**Shelf life of the butters**

The counts of microorganisms in fresh butter samples and their behaviour in traditional and industrial butters during storage are shown in Figure 3.

The initial microbiological load differed significantly between butter samples (MANOVA \(p<0.05\) with ANOVA and Tukey post-hoc \(p<0.05\)). Sample BU was characterised with the highest initial counts of all the microorganisms, while samples CS 1, DU and DU 1 did not contain any above the limit of detection. In the remaining samples, Enterobacteriaceae and yeast and moulds were not detected, but various levels of ACC and *Pseudomonas* spp. (ranging from under the limit of detection to 3.89 log10 cfu g\(^{-1}\)) were found.

During the whole storage period, the industrial butters contained significantly lower numbers of all microorganisms compared to the traditional butters (\(p<0.05\) repeated measures ANOVA). Whilst the microorganism growth curves for industrial butters looked flat, an appreciable growth of all tested microorganisms took place in the traditional butters between the 1\(^{st}\) and 8\(^{th}\) week of storage.

Not all of the traditional butters supported microbial growth to the same extent. The traditional butter with the fastest mean growth rate for all three groups of spoilage microorganisms was BS butter (mean growth rates ranging from 0.158 to 0.226 log cfu g\(^{-1}\) week\(^{-1}\)). Microorganisms grew more slowly on the other traditional butters (mean growth rates ranging from 0.018 to 0.154 log cfu g\(^{-1}\) week\(^{-1}\). This was faster than growth on industrially produced butters (mean growth rates ranging from 0 to 0.053 log cfu g\(^{-1}\) week\(^{-1}\)). The microbiological growth had a notable impact on the shelf life of some butters. The growth of mould was visible on the surface of butters BU and BS after 8 weeks of storage, and by week 24 on butters DU and AU.

Butters DU 1, DS, CS and CS 1 did not develop visible mould over the duration of the study. In addition, the visible growth of moulds in affected butters appeared well after declared best before dates. All the manufacturers judged the shelf life of their butters correctly.

The results of the measurements of peroxide and acid values in fresh and stored butters are summarised in Figure 4.

Acid values of fresh butter oils ranged from 0.12 to 0.42 % m/m as oleic acid. The highest acid value was obtained for BU sample (\(p<0.05\), ANOVA with Tukey post-hoc). The acid value did not differ significantly between the rest of the butter samples.

Peroxide values in fresh butter ranged from 0.0724 to 0.91 mEq O\(_2\) kg\(^{-1}\) and statistically significant differences were observed (\(p<0.05\), ANOVA with Tukey post-hoc). In a group of samples with high peroxide values (above 0.6 mEq O\(_2\) kg\(^{-1}\)) butters AU, BS, DU and DU1 were identified, whereas low peroxide values (below 0.3 mEq O\(_2\) kg\(^{-1}\)) were noted in CS, CS1 and DS butter oils.
Peroxide and acid values increased in traditional and industrial butters through the period of storage. The trends in changes of peroxide value were similar in both butter groups, however the acid value seemed to increase slightly faster in traditional compared to industrial butters.

The water dispersion differed between butter samples. It was the worst in sample BS (large droplets covering a large area of the indicator paper) and best in sample DU (very fine droplets, nearly invisible, and evenly distributed over the indicator paper). Pearson’s R coefficients resulting from the correlation of water dispersion ranks given to the samples with microbiological growth rates and increases of peroxide and acid values through 24 weeks of storage are shown in Figure 5 summarised in Table III. Pearson’s R correlation coefficients ranged from -0.8558 to 0.5885 and were statistically significant for correlations of Pseudomonas spp. and yeast and moulds growth rates with ranked water dispersion level (regression analysis, p<0.05). The lowest positive and the only negative correlation coefficient was obtained with the mean increase of peroxide value, whereas the highest positive correlation was with the mean growth rate of yeasts and moulds.

Discussion

Sensory quality of the butters

This study has shown that consumers may have preferences for certain butter types. In unsalted butters the aroma and flavour compounds may play a more significant role compared to salted butters. The VOC profile will depend on many factors, including the type of the cream that is used for the butter. British manufacturers of traditionally-made butter may utilise sweet cream, whey cream, or clotted cream. Sweet cream butters are the most popular type of butter in the UK (Fernandes, 2009), which may mean that consumers are more accustomed to them and perceive their taste more favourably. In this study the panellists awarded the highest sensory score to traditional sweet cream butter in the group of unsalted butters, which was significantly higher compared to the score for industrial sweet cream butter. This could be a result of buttermilk retention and spread in the butter block. Some authors emphasize that the buttermilk contains flavour and aroma compounds, removal of which impoverishes the sensory quality of the butter (Spreer, 1998). Nevertheless, this study has also shown that the addition of flavour inducing compounds- diacetyl and lactic acid (in DU1 industrial butter), helps to increase the palatability of the butter.

Whey cream butters are known to have a different odour and flavour compared to sweet cream butters (Jinjarak et al., 2006). Our research has shown that this difference does not affect the palatability of the butter negatively, since the whey cream butter has been graded on par with industrial sweet cream butter.

Clotted cream butter was assessed in a group of salted butters. In this group of butters the effect of differences in VOCs seemed to be diminished due to saltiness. Butters at 2% salt addition received higher scores than butters salted at 1.5%, however these differences were not statistically significant.

Flavour and odour inducing compounds

The type of cream used and the additives included in the butter formulation influenced the VOC profiles. A recent study of the VOCs in sweet-cream butter nominated 26 compounds responsible for its flavour and aroma, This list includes lactones, acetaldehyde, and decanoic acid (Tamura et al., 2021). All four butter samples tested in the current study contained acetaldehyde (pungent, fruity, green aroma; Tamura et al., 2021); delta-hexalactone and delta-octalactone (sweet and buttery aroma and mild, coconut flavour respectively; Saittagaroon et al., 1984) as well as delta-decalactone (coconut-peachy flavour;
Boratyński et al., 2018). Whey cream butter AU contained the least lactones, while acetaldehyde was highest in industrial butter DU1.

DU1 was made using a variant of the NIZO process. After the removal of most of the sweet cream buttermilk, lactic acid and diacetyl preparations were worked into the butter grains to mimic cultured cream butter. This resulted in a large peak on the GC-MS for diacetyl, which confers the buttery odour found in cultured cream butters (Fernandes, 2009; Wilbey, 2009). According to Tamura et al. (2021) stated diacetyl should be absent in sweet cream butters. Nevertheless, because it is not fermented product, in the present work, diacetyl was found in all butters, including sweet-cream butters.

The preparations used to adjust butter DU1 are a proprietary technology. We detected more short-chain fatty acids in DU1 than other butters, and suspect these acids contributed to the desired odour.

The whey cream butter contained the lowest responses for the most abundant VOCs with the exception of toluene. This compound is found in higher quantities in butters obtained from cows grazing on pastures (O’Callaghan et al., 2016), indicating that dairy cows from which the AU butter was obtained were grazing rather than fed and kept indoors.

**Shelf life of the butters**

According to Adams and Moss (2008), freshly made butter should not contain more than 3 log$_{10}$ cfu g$^{-1}$ for ACC. All the industrial butters, and two out of five traditional butters, satisfied this criterion. In one of the samples (BU), the ACC count exceeded 5 log$_{10}$ cfu g$^{-1}$ which, according to the Health Protection Agency (2009), is a level that may indicate a need of further investigation into sources of butter contamination. This sample also contained a high number of other assessed microorganisms, including Enterobacteriaceae, which are a food hygiene indicator, readily killed during pasteurisation, but present in food production environment (Health Protection Agency, 2009). High initial microbiological counts in a sweet cream butter may be a consequence of either or all: high microbiological counts in cream; butter and cream handling during and post production and insufficient removal of the buttermilk.

Traditional butters were good growth media for spoilage microorganisms. Significant correlations were noted between rankings of water dispersion and mean microbiological growth rates for *Pseudomonas* spp., and yeasts and moulds, within the studied samples. Poor water dispersion and insufficient buttermilk removal may allow the growth of microorganisms (Adams and Moss, 2008; Berthold-Pluta et al., 2013), which manifested itself as colonies of moulds appearing on two traditional butter samples after 8 weeks of refrigerated storage.

Initial fat rancidity measurements showed that most of the samples were of acceptable quality. Only one sample (BU) exceeded the criterion of 0.4 % m/m as oleic acid for acid value in butter oil (FAO and WHO, 2011), however there were no off-odours indicating butter spoilage. In fact, acid value of 0.4 % m/m as oleic acid is seen as a generalised consensus but through the literature, varying levels, between 0.2 up to even 0.7 % m/m as oleic acid were recommended by the authors (Deeth and Fitz-Gerald, 2006). Many authors have also reported that there was no correlation between the acid value and the ‘lipase’ defect (Deeth and Fitz-Gerald, 2006). In fresh butters the acid value might be higher if the buttermilk is removed to a lesser extent. The buttermilk contains a large proportion of water-soluble, short-chained acids C4:0 and C6:0 which have a positive impact on the flavour of the butter but would also increase the acid value (Mcdaniel et al., 1969). This could explain, why the BU butter, which had a high score for sensory characteristics, was also characterised with the highest acid value among tested samples. Munro et al. (1998) stated peroxide values above 0.3 mEq O$_2$ kg$^{-1}$ are associated with detectable deterioration of the fat quality in butter. Another source gives a threshold of 0.62 mEq O$_2$ kg$^{-1}$ for peroxide values of cultured cream butter (Bakirci et al., 2002). However, in the current study, values for three of the samples exceeded 0.8 mEq O$_2$ kg$^{-1}$, with no undesirable odour or flavour...
development. This may mean that peroxide value should be a parameter assessed individually for
distinct butter products.

There was also a trend for changes in acid values and peroxide values during the storage of butter to
correlate with the level of water dispersion. Better water dispersion implied a faster progress of
oxidative rancidity and a slower progress of hydrolytic rancidity. Water shields the fat from the
atmospheric oxygen, but on the other hand is also an environment for enzymatic, including lipolytic
reactions (Feiner, 2016; Irwin and Hedges, 2004).

All butter manufacturers judged the shelf life of their butters correctly and in most cases, as longer than
that suggested by recent literature, where for unsalted butters authors claim up to 2 weeks and for salted
up to 2 months shelf life under refrigerated conditions (Lee et al., 2018).

Conclusions

In this pilot-scale study we have defined the meaning of “traditional” butter production in UK. What is
meant by traditional butter production is batch processing of various types of cream and in most of the
cases hand forming of the butter. The processing is carried out in hygienic conditions, using churners
from easily sanitised materials.

It was found that traditional unsalted butters may be indeed preferred by the consumers to industrially
produced, high quality butters, although it needs to be emphasized that our results are based on samples
collected from only one large-scale butter producer. Assessed butters were shown to contain very
different volatile organic compounds impacting aroma and flavour of the products. 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.

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 was found to be positively
correlated with the growth of Pseudomonas spp., and Yeasts and Moulds, which tended to be faster on
traditional compared to industrial butters. Faster growth of microorganisms and higher initial
microbiological load found on some of the traditional butter samples resulted in a shorter shelf life of
these products. Nevertheless, it has to be noted that all the butter manufacturers assessed the shelf life
of their products correctly. The shelf life of traditional butters could be increased by an improvement
of the water dispersion, and a reduction of the initial microbiological contamination by removal of
buttermilk to a greater extent. Nevertheless, more diligent buttermilk removal may also wash out 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, although poor water dispersion seemed to hasten the progress of lipolytic rancidity in some
traditional butters.

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 unambiguously confirm
the claim that 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.

Prolonged lockdowns due to the current COVID-19 pandemic pose a threat to the food supply chain,
and food produced by local manufacturers may become increasingly important. Therefore the research
on the small-scale, local and artisanal food production practices is important and should provide
information on the challenges faced by the manufacturers and possible solutions. The findings of this
study provide insights into possible improvements that could be made to prolong the shelf life and improve the quality of the traditional butter. Further, they are also informative for the general public who increasingly seeks for local and artisanal high quality foods.

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References


10 ISO 4833-2:2013, “Microbiology of the food chain -- Horizontal method for the enumeration of microorganisms -- Part 2: Colony count at 30 degrees C by the surface plating technique”

11 ISO 6887-1:1999, “Microbiology of food and animal feeding stuffs — Preparation of test samples, initial suspension and decimal dilutions for microbiological examination — Part 1: General rules for the preparation of the initial suspension and decimal dilutions”.


### Table I- Characteristics of collected butter samples

<table>
<thead>
<tr>
<th>Sample identification</th>
<th>Factory</th>
<th>Butter manufacture</th>
<th>Declared salt content</th>
<th>Cream type used for production</th>
<th>Other additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU</td>
<td>A</td>
<td>Traditional</td>
<td>None</td>
<td>Whey</td>
<td>None</td>
</tr>
<tr>
<td>BU</td>
<td>B</td>
<td>Traditional</td>
<td>None</td>
<td>Sweet*</td>
<td>None</td>
</tr>
<tr>
<td>BS</td>
<td>B</td>
<td>Traditional</td>
<td>0.5%</td>
<td>Clotted</td>
<td>None</td>
</tr>
<tr>
<td>CS</td>
<td>C</td>
<td>Traditional</td>
<td>1.5%</td>
<td>Sweet*</td>
<td>None</td>
</tr>
<tr>
<td>CSI</td>
<td>C</td>
<td>Traditional</td>
<td>2%</td>
<td>Whey and Sweet*</td>
<td>None</td>
</tr>
<tr>
<td>DU</td>
<td>D</td>
<td>Industrial</td>
<td>None</td>
<td>Sweet*</td>
<td>None</td>
</tr>
<tr>
<td>DU1</td>
<td>D</td>
<td>Industrial</td>
<td>None</td>
<td>Sweet*</td>
<td>Lactic Acid and Diacetyl</td>
</tr>
<tr>
<td>DS</td>
<td>D</td>
<td>Industrial</td>
<td>2%</td>
<td>Sweet*</td>
<td>None</td>
</tr>
</tbody>
</table>

*Sweet refers to pasteurised, uncultured cream


Table II- Differences in butter production practices in visited production plants

<table>
<thead>
<tr>
<th>Production step</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cream storage temperature (°C)</strong></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Cream storage time (days)</strong></td>
<td>Up to 3</td>
</tr>
<tr>
<td><strong>Maximum volume of the cream for a single churning (l)</strong></td>
<td>135</td>
</tr>
<tr>
<td><strong>Temperature of the cream admitted to the churner (°C)</strong></td>
<td>10-12</td>
</tr>
<tr>
<td><strong>Churning time (min)</strong></td>
<td>20-70</td>
</tr>
<tr>
<td><strong>Buttermilk separation</strong></td>
<td>Drained by opening churner’s bottom valve, butter is then washed with water</td>
</tr>
<tr>
<td><strong>Mixing salt and additives</strong></td>
<td>In a churner while kneading</td>
</tr>
<tr>
<td><strong>Duration of the process (min)</strong></td>
<td>90 to 120</td>
</tr>
<tr>
<td><strong>Butter temperature prior to forming (°C)</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Butter forming</strong></td>
<td>250 g portions are weighted and rolled by hand, then formed using wooden scotch hands</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>By hand in cellophane</td>
</tr>
<tr>
<td><strong>Claimed shelf-life (weeks)</strong></td>
<td>12</td>
</tr>
</tbody>
</table>
Previous caption: Figure 5- Pearson’s R correlation coefficients of water dispersion ranks given to the samples with mean microbial growth and peroxide and acid values increase rates during storage at 5˚C for up to 24 weeks. *above a column marks statistical significance.

Table III- Pearson’s R correlation coefficients of water dispersion ranks with mean microbial growth and peroxide and acid values increase rates during storage at 5˚C for up to 24 weeks

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>ACC</th>
<th>Pseudomonas spp.</th>
<th>Yeast and moulds</th>
<th>Acid value</th>
<th>Peroxide value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r</td>
<td>-0.66</td>
<td>-0.82*</td>
<td>-0.85*</td>
<td>-0.70</td>
<td>0.58</td>
</tr>
</tbody>
</table>

* marks statistical significance.
Figure 1 - Results of the sensory evaluation of unsalted (a) and salted (b) butters. Error bars represent interquartile range for sensory scores from 15 evaluators, while columns median scores. Different letters above different columns belonging to the same butter trait, mark a statistically significant difference.

Previous caption: Figure 1 - Results of the sensory evaluation of unsalted (a) and salted (b) butters. 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: Selection of 14 prominent volatile organic compounds detected over butter samples.

Previous caption: Figure 1: Selection of 14 prominent volatile organic compounds detected over butter samples.
Figure 3 - Initial microbiological load on individual butter samples for (a) ACC, (b) *Pseudomonas* spp., (c) yeast and moulds, (d) Enterobacteriaceae; and growth curves of (e) ACC, (f) *Pseudomonas* spp. and (g) yeast and moulds on traditional and industrial butters stored at 5°C for up to 24 weeks. Columns and data points correspond to the mean microbiological count while error bars to the standard error. Counts below the LOD were expressed as 50% LOD value for raw counts. Respective LODs were marked with black, dotted line on each graph. Different letters above different columns or lines in the same graph mark a statistically significant difference.
Previous caption: Figure 1- Initial microbiological load on individual butter samples for (a) ACC, (b) Pseudomonas spp., (c) yeast and moulds, (d) Enterobacteriaceae; and growth curves of (e) ACC, (f) Pseudomonas spp. and (g) yeast and moulds on traditional and industrial butters stored at 5°C for up to 24 weeks. Columns and data points correspond to the mean microbiological count while error bars to the standard error. Counts below the limit of detection: 1 log cfu g⁻¹ for Enterobacteriaceae and 2 log cfu g⁻¹ for remaining microorganisms were expressed as half of the limit of detection value for raw counts. Different letters above different columns or lines in the same graph mark a statistically significant difference.
Figure 4- Fat rancidity measurements- initial acid (a) and peroxide (b) values of butter oils in individual butter samples, as well changes of acid (c) and peroxide (d) value in traditional and industrial butters stored at 5˚C for up to 24 weeks. Columns and data points correspond to the mean values while error bars to the standard error. Different letters above different columns or lines in the same graph mark a statistically significant difference.