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Physicochemical profiles and sensory differences in German fluid milk products: traditionally pasteurized, extended shelf life, and ultra-high-temperature processed

Chemisch-physikalisches Profil und sensorische Unterschiede bei deutschen Konsummilchsorten: traditionell hergestellt, länger haltbar (extended-shelf-life, ESL) und ultrahocherhitzt

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Summary

Currently, fluid, non-flavoured milk products in Germany comprise traditionally produced (TP, i. e., pasteurized), ultra-high treatment processed (UHT), and extended shelf life (ESL) milk. Manufactured basically by high-temperature treatment (HTT) or microfiltration, ESL milks were advertised as pasteurized milks with an extended shelf life. However, ESL milks introduction was debated strongly rising doubts regarding its compositional and sensorial quality and fearing deceit as labelling were insufficient. The objective of this study was a) to evaluate the gross chemical composition of TP, ESL (HTT) and UHT milk at the beginning and at the end of shelf life, and to b) submit TP and ESL milk to a sensory evaluation by laymen. For trial 1, milk of all types from one single manufacturer were purchased and submitted to standard chemical and physical analysis (protein, fat, lactose, calcium, pH, titratable acidity, dry matter, density, freezing point, alkaline phosphatase, and peroxidase) and analysed at the beginning and the end of shelf life. In trial 2, TP and ESL were evaluated using a triangle test-based design. Regarding chemical and physical variables, HTT milk ranged between TP and UHT values, showing eventually more similarity to one of these classic fluid milks. Still, all quality requirements were met by all three milks. The sensory testing showed that TP and ESL were clearly distinguished by the panellists. All results suggested that all fluid milk types represent products with individual properties rather than ESL milk being a variety of TP or UHT milk.

Keywords: triangle test, milk composition, milk quality, milk flavour, thermal treatment

Zusammenfassung

Gegenwärtig werden auf dem deutschen Markt traditionell hergestellte (d. h. pasteurisierte; TP), ultrahocherhitzte (UHT) und länger haltbare (extended shelf life, ESL) Konsummilch angeboten. Zumeist durch Hocherhitzung oder Mikrofiltration hergestellt, wurde ESL-Milch anfangs als länger haltbare Frischmilch vertrieben. Die Markteinführung war umstritten und wurde durch Zweifel an der kompositionellen und sensorischen Beschaffenheit sowie Unsicherheit der Verbraucher aufgrund der als unzureichend empfundener Etikettierung begleitet. In dieser Studie sollte a) die chemisch-physikalische Beschaffenheit von TP-, ESL-(HTT)- und UHT-Milch zu Beginn und Ende der Haltbarkeit untersucht und b) frische TP- und ESL-Milch einer sensorischen Prüfung durch Laien unterzogen werden. Für Versuch 1 wurden alle Milchsorten bei demselben Hersteller eingekauft und routinemäßigen chemischen und physikalischen Untersuchungen (Eiweiß, Fett, Laktose, Kalzium, pH-Wert, SH-Wert, Trockenmasse, Dichte, Gefrierpunkt, alkalische Phosphatase, Peroxidase) zum Anfang und zum Ende der Haltbarkeit unterzogen. In Versuch 2 wurde ein auf der Dreiecksprüfung basierter Test verwendet, um sensorische Unterschiede zwischen TP- und ESL-Milch festzustellen. Das chemisch-physikalische Profil von ESL-(HTT)-Milch war zwischen dem von TP- und UHT-Milch einzuordnen, wobei einige Variablen mehr den Werten der TP-, andere mehr denen der UHT-Milch ähnelten. Dennoch erfüllten alle Sorten die Qualitätsanforderungen. Bei der sensorischen Analyse unterschieden die Testpersonen deutlich zwischen ESL- und TP-Milch. Diese Ergebnisse legen nahe, dass es sich bei ESL-Milch nicht um eine Variante von TP- oder UHT-Milch handelt, sondern dass alle drei Konsummilchtypen eigenständige Sorten darstellen.

Schlüsselwörter: Dreieckstest, Milchzusammensetzung, Milchqualität, Milchgeschmack, Wärmebehandlung

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1 Introduction

Milk is a complex mixture of water, fat, proteins, carbohydrates and many more substances. Its complexity leads to a short shelf life, but the latter is increased by treating milk thermally. In fact, a longer shelf life was a secondary effect, being the inactivation of milk-borne pathogens (e. g. *Mycobacterium tuberculosis,* EHEC etc.) the prime reason for heating milk.

In Germany, ESL milks were introduced by 1990. After years of static markets for fluid milk, they were considered to be a solution for the consumers' demands for wholesome, tasty and convenient (shelf life of 2 to 4 weeks) fluid milk on one hand, and to the industry's demand for more advantageous logistics for dairies, retail and consumers (answering to the observed reduced shopping cycle) on the other hand. The need for more complex manufacture processes, highest hygiene standards and optimum cooling chains (which leads to more elevated costs of production) were regarded as disadvantages for the industry (Schöne, 2003; Rysstad and Kolstad, 2006). At present, two major types prevail:

- purely high temperature-treated (HTT) ESL milk which is subjected to 120 to 127 °C for 1–4 seconds (or 135 °C for 0.5 seconds) by applying direct heat as steam either via injection or infusion (falling stream heater) or indirect heat (plates), e. g. at 125 °C for 2 seconds.
- filtrated ESL milk in which the separated cream is also treated with high temperature while the skim milk becomes filtrated (microfiltration or deep bed filtration) and afterwards pasteurized (Gallmann et al., 2001; Kiesner, 2001; Rysstad and Kolstad, 2006; Thomet, 2006; Könneke, 2008; Kaufmann et al., 2010; Mayer et al., 2010).

The segment for ESL milks increased (mostly by reducing the one for pasteurized milk, eventually from 28 to 0 %, depending on the supermarket chain), and these milks were labelled as 'pasteurized' since UHT temperature/time profiles were not applied. German consumers that traditionally chose pasteurized milk criticized this ambiguous labelling, because they were not any longer able to differentiate between traditionally processed (TP) and ESL milk. Terms like "fresh", "maximum fresh" or "fresh for a longer period" were interpreted as misleading, and a debate on the compositional quality of ESL milks (e. g. vitamin content) was initiated. Consumer protection agencies called for government intervention, and the involved parties agreed on a voluntary additional labelling that would include the term "longer lasting" and the heat treatment employed for the product in question, but this was not set into practice by many dairies (Hagemann [personal communication, 2010]) detected missing data in 45.5 % of sampled ESL packages; n = 22), so the debate lingers on (Pix, 2008; AFP, 2009; Anon., 2009; Kaufmann et al., 2009, 2010).

Data on differences and similarities between ESL and other types of milk are scarce or contradictory, as in the case of vitamin content. Some works deal with microbiological (Gallmann et al., 2001; Rysstad and Kolstad, 2006; LAVES, 2009); physicochemical (Cano Ruiz and Richter, 1998; Gallmann et al., 2001; Eberhardt et al., 2003; Hoffmann et al., 2006; Vázquez Valverde et al., 2006; LAVES, 2009; Kaufmann et al., 2010; Mayer et al., 2010) and sensory (Santos et al., 2003; Rademacher and Hülsen, 2005; Van Aardt et al., 2005, Kaufmann et al., 2010). In many other cases, changes in ESL milk are inferred by using TP and/or UHT milk as models.

In the present study, TP, ESL and UHT milks from one single manufacturer in Germany were compared directly at the beginning and at the end of the corresponding shelf lives, using a series of physicochemical analysis to contribute to a scientifically-based discussion on the quality of fluid milk products.

During a symposium ("II. Hannoverscher Milchtag", 2012), a sensory examination based on a triangle test was done with a part of the auditorium as spontaneous panellists.

2 Materials and Methods

Commercially-produced fluid milks (TP, ESL, UHT) presented in packages of 1 liter were purchased on the day of production from a German dairy that trades all three types regularly. Storage was at 4 °C (TP, ESL) and ambient temperature (UHT). Analysis started the day after purchase. Milk samples were evaluated using sensory and physicochemical methods.

2.1 Trial 1: physicochemical profile

Sampling was done at the beginning (i. e., the day after manufacture) and the end of corresponding shelf life.

Milk samples were tested for a series of parameters that reflect, in the first place, milk quality as defined by European and German standards (Tab. 1). Most of them are official and mandatory on certain government levels – eventually only for certain production stages – while others (i. e. lactose and calcium [Ca]) were included despite this official recognition, as they still reflect milk quality (Riemelt, 2006). From the five German quality parameters (which, just like the corresponding data in EC regulation 853/2004, were established for raw milk), the somatic cell count and total bacterial count were omitted in the present investigation because they are not part of the physicochemical parameters. Two enzymes (alkaline phosphatase and peroxidase) were included in the analysis because they are the basic tools to determine the heat treatment:

TABLE 1: *Microbiological, cytological and chemical parameters; methods commencing with "L01" refer to official methods as defined by § 64 of the German "Code for Foods, Commodities and Feeds"* (Lebensmittel-, Bedarfsgegenstände- und Futtermittelgesetzbuch, LFGB). *Parameters specified by 853/2004 were determined using LFGB methods.*

parameter class	parameter	unit	analysis method used
EU regulation 1234/2007	protein content	%	infrared spectroscopy
	fat content	%	infrared spectroscopy
	density	g/l	L01.02-10 (hydrometry)
"Milk Quality Regulation" *(Milch-Güte-Verordnung)* (federal level)	protein, fat	%	infrared spectroscopy
	freezing point	°C	cryoscopy
additional quality regulations (German state level)	dry matter	%	calculation
	dry matter free of fat	%	calculation
	density	g/ml	L01.02-10 (hydrometry)
	pH	–/–	electrochemistry
	SH (titratable acidity)	°SH	L01.00-7 (Soxhlet and Henkel method), modified*
	alkaline phosphatase	pos./neg.	enzyme reaction (Lactognost Heyl®)
	peroxidase	pos./neg.	enzyme reaction (Traventol®)
unofficial parameters	lactose	%	infrared spectroscopy
	calcium	%	complexometry

*= test was made with 25 ml of sample only, but results were multiplied by 4 in order to be based on 100 ml of milk

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Common time-temperature combinations may be detected by in the inactivation of those enzymes, with alkaline phosphatase being inactivated below TP and peroxidase below UHT processing.

However, these parameters still represent a selection; EU regulation claims that milk has to be analyzed for inhibiting substances (853/2004; raw milk) as well as for listeriae (2073/2005; pasteurized milk). Local German authorities also (used to) test raw and pasteurized milk for a series of other pathogens. However, HACCP systems are well-established to cope with these dangers in dairy factories, and so these parameters were neglected.

While fat, protein, freezing point, and lactose were measured at an official dairy herd improvement laboratory (Milchwirtschaftlicher Kontrollverband Mittelweser, Rehburg-Loccum, Lower Saxony, Germany), the additional quality parameters and calcium determination were done in the installations of the authors' institute.

For every milk type, n = 5 packages were sampled. From each package, two samples were drawn and in the case of pH, each sample was measured twice.

2.2 Trial 2: sensory evaluation

Fluid milks and other dairy products may be tested readily with a growing set of national and international standards (Westmair 2008). During a symposium dealing with dairy products and quality in Hannover, TP, ESL (HTT) and UHT was purchased and offered to the auditorium during coffee break. Before the break, it was invited to participate in this triangle-like test, and the frame conditions were explained., A triangle-based test (the original test refers to ISO 4120 [2004, German version EN ISO 4120:2007]) was chosen because this test provides results that are rated unbiased (unlike affective tests) and statistically more reliable in comparison to other sensory tests. Based on a forced choice principle, this test focuses on detecting the one sample out of three which tastes differently, so there was no definition of "quality" used in for these trials.

The panel consisted of volunteering persons of all ages from the auditorium, and panellist claimed to have little or no experience in performing sensory trials with fluid milks. No panellist was eliminated from the trial. Milk packages were permitted to acquire ambient temperature and samples of 100 ml each were poured into white disposable vending cups (0.2 l). Each vending cup was marked with a letter (a, b, c) and contained either TP (two cups) or ESL (one cup) milk.

Each participant was offered all three cups. Samples were swallowed and bread and/or water consumed between samples. Panellists were asked to name the sample that tasted different from the other two by voting electronically (PowerVote™).

2.3 Statistical analysis

The physicochemical variables were analyzed for normal distribution and eventually transformed into 10-base logarithms (lg]. Influences by the factors "time" and "milk type" were calculated by bifactorial analyses of variance (in the first case, including repeated measurements). Description of the data comprised means ([i. e. x_a]), standard deviations (sd) and sample sizes (n). The level of significance was set to $p < 0.05$. As analyses at the onset and the end of shelf life were made with different packages, two-sample t-tests were performed.

Sensory evaluation was analyzed according to the tables presented in appendix A of ISO 4120 and expressed in percentage of correct answers. This appendix contains the minimum of correct answers in relation to the total amount of panellists and the level of significance (α) at which this result turn significant. When the exact amount of panellists is not contained in the appendix, this may be calculated via the normal approximation of the binomial distribution.

3 Results and Discussion

3.1 Study design

In order to start off from conditions that were as homogeneous as possible, a dairy brand was chosen which offered all three types of liquid milks, supposing that the milk they used would be comparable. This by itself was a difficult task as most German diaries offer only one or two types of liquid milk. However, even if the company chosen traded all three types, TP milk was produced at a different plant than the ESL and UHT milks were. So, there is a slight possibility that initial milks were not comparable. However it can be expected that the company applied the same quality standards in all plants so that differences, if existing, were but slight.

Regarding the sensory evaluation it has to be stressed that the method used was based on the triangle test but the testing conditions differed from the ordinary design due to the nature of the event that summoned the panellists. The triangle test is usually performed in single cabins in neutral rooms, there is no interaction between panellists while evaluating the samples, and three triads are offered subsequently to each panellist in order to display all possible combinations. Here, tasting the milk samples occurred in a symposium accommodation during coffee break, where talking among panellists could not be avoided, and only one triad was served. A sensory deprivation as would be beneficial for all sensory tests could not be guaranteed (coffee, nicotine), so that the result obtained by the test in the present study should be interpreted with caution.

3.2 Evaluation of heat treatment

The enzyme test reacted as expected, i. e. negative results for alkaline phosphatase in all milk samples, and positive peroxidase results in pasteurized milk, and negative ones for ESL and UHT milk.

The methods used for the present trial appear out of date, since the measurement of other heat-dependent substances (e. g. lactulose, furosin, lacto globulins) is used in the dairies, especially in the case of ESL milks. These methods however require much more investment in chemicals, equipment and staff (Mayer et al., 2010) than these rapid methods. Besides, a tendency to group ESL milks into peroxidase-positive and peroxidase-negative milks would turn this test at least into a screening method. Still, Austrian authors (Mayer et al., 2010) found that elevated furosin resp. reduced acid-soluble β-lacto globulin contents detected in ESL milks suggested much more severe heat treatments as supposed which in turn would make it difficult to differentiate between UHT and ESL milks (putting thus in question the "image" of ESL milks). However, it must be remembered that one and the same effect may be achieved by many different temperature/time profile, and that ESL comprises a great variety of technologies. In any way, this issue needs attention and the

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authors stress the importance of government intervention to establish binding thresholds, e. g. 1800 to 2000 mg/l for β-lacto globulin.

3.3 Physicochemical profiles

From a general point of view, the lactose content, pH and titratable acidity (SH) were the variables affected most strongly by milk type and/or storage, and while all other variables were affected by at least one factor (Tab. 2), Ca content remained generally constant (0.12–0.14 %; Tab. 3 and 4), which contrasts with worried consumers who suppose a reduced mineral content of ESL milks. However, Ca is known to be a very stable milk ingredient in fluid milks once the milk has been heated (El-Deeb, 1987).

All products started with the same density and SH values, while calcium and pH were similar in pasteurized and ESL milks. For the rest of the parameters, significant differences were calculated (Tab. 3).

Protein and density remained unchanged during the entire shelf life in all milk types (Tab. 4). In all other cases, parameters tended to maintain initial levels in at least one milk type but changed in the remnant ones toward the end of shelf life. In this manner, fat, freezing point, dry matter, and lactose values decreased, while dry matter free of fat, pH, and SH levels either decreased or increased in relation to the milk type.

Thermal treatment of milk translates into specific temperature/time profiles that change milk composition. However, the quality and the degree of changes vary between heating protocols, and so the significant differences in composition among the different milk types show clearly that, from the compositional point of view, each of them represents an individual product. In fact, the sensory changes discussed before are the reflection of these processes. The values presented in Tab. 3 and 4 support this assumption as some parameters in the case of ESL initially resembled TP (pH) levels (Tab. 3). Protein levels in ESL were intermediate between TP and UHT, but for most other parameters, ESL production seems to increase dry matter (i. e., reducing water content), specifically shown by increased fat and lactose values. Overall, titratable acidity was the same in all milks, showing that the samples were indeed "fresh". However, most differences ranged on a very low scale. Still, with the markedly small standard deviation and the fact that only milk from one producer was sampled, it may be assumed that these differences reflect technological influences.

To evaluate these changes, the results were compared with the reference values (Tab. 5); where no official references existed, significant literature was presented instead. It was seen that most parameters were within the expected ranges. However, some differences occurred.

With 3.47 % (Tab. 3 and 4), the fat content in TP was slightly lower than established by regulation (EC)

TABLE 2: *Factors of influence on the microbiological, cytological and physicochemical variables.*

Variable	Influence by … … milk type p value	… milk type F value	… shelf life p value	… shelf life F value	… milk type x shelf life p value	… milk type x shelf life F value
protein	< 0.001	12.89	< 0.05	4.50	n .s.*	–
fat	< 0.001	9.51	n. s.	–	< 0.05	5.12
freezing point	< 0.001	75.52	< 0.001	46.09	< 0.01	7.52
dry matter	< 0.001	67.12	< 0.05	4.92	< 0.001	15.05
dry matter free of fat	< 0.001	92.47	< 0.05	10.57	< 0.001	27.97
density	< 0.001	42.00	< 0.01	10.67	< 0.001	18.67
pH	< 0.001	515.82	< 0.001	29.88	< 0.001	64.45
SH (titratable acidity)	< 0.001	120.20	< 0.001	74.31	< 0.001	119.06
lactose	< 0.001	1213.59	< 0.001	144.11	< 0.001	42.42
calcium	n. s.	–	n. s.	–	n. s.	–

*n. s. (non-significant) corresponds to a p value >0.05

TABLE 3: *Physicochemical, cytological and microbiological parameters [mean ± standard deviation] at the beginning of the shelf life of traditionally pasteurized, ESL and UHT milk (n = 5 each); different superscripts within rows indicate significant differences (p < 0.05).*

Parameter	unit	TP	ESL	UHT
protein	%	3.34 ± 0.00[a]	3.35 ± 0.00[b]	3.42 ± 0.00[c]
fat	%	3.47 ± 0.00[a]	3.51 ± 0.00[b]	3.50 ± 0.00[c]
freezing point	°C	–0.523 ± 0.001[a]	–0.526 ± 0.001[b]	–0.523 ± 0.001[ab]
dry matter	%	12.57 ± 0.16[a]	12.78 ± 0.04[b]	12.57 ± 0.03[a]
dry matter free of fat	%	9.10 ± 0.16[ab]	9.27 ± 0.04[a]	9.07 ± 0.03[b]
density	g/ml	1.032 ± 0.001		
pH	–/–	6.72 ± 0.03[a]		6.56 ± 0.01[b]
SH (titratable acidity)	°SH	6.11 ± 0.67		
lactose	%	4.78 ± 0.00[a]	4.85 ± 0.00[b]	4.73 ± 0.00[c]
calcium	%	0.13 ± 0.01[a]		0.14 ± 0.01[b]

TABLE 4: *Milk quality parameters [mean ± standard deviation] at the beginning and at the end of shelf life. When no significant differences were encountered, 'start' and 'end' means were merged into a single value, otherwise p < 0.05.*

Parameter	unit	TP start	TP end	ESL start	ESL end	UHT start	UHT end
protein	%	3.35 ± 0.04		3.34 ± 0.01		3.40 ± 0.05	
fat	%	3.47 ± 0.00	3.45 ± 0.01	3.51 ± 0.00	3.50 ± 0.01	3.54 ± 0.01	
freezing point	°C	–0.523 ± 0.001	–0.525 ± 0.000	–0.526 ± 0.001		-0.523 ± 0.001	
dry matter	%	12.50 ± 0.13		12.86 ± 0.10		12.57 ± 0.03	12.33 ± 0.11
dry matter free of fat	%	9.04 ± 0.13		9.27 ± 0.04	9.45 ± 0.07	9.07 ± 0.03	8.74 ± 0.02
density	g/ml	1.031 ± 0.001		1.033 ± 0.000		1.031 ± 0.001	
pH	–/–	6.72 ± 0.02		6.72 ± 0.03	6.84 ± 0.01	6.56 ± 0.01	6.52 ± 0.02
SH (titratable acidity)	°SH	6.65 ± 0.65		5.68 ± 0.18	5.20 ± 0.20	6.00 ± 0.28	10.80 ± 0.25
lactose	%	4.80 ± 0.01		4.85 ± 0.00	4.81 ± 0.01	4.73 ± 0.00	4.69 ± 0.00
calcium	%	0.13 ± 0.01	0.14 ± 0.01	0.13 ± 0.01	0.12 ± 0.00	0.14 ± 0.01	

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TABLE 5: *Reference values and ranges for the chemical, cytological and microbiological parameters.*

Parameter	unit	reference value	source
protein	%	≥ 2.90	EU regulation 1234/2007
fat	% %	≥ 3.50 ≥ 3.00	EU regulation 1234/2007 "Milk and Fat Law" *(Milch- und Fettgesetz)*
freezing point	°C	"not on spec of added water" ≤ –0.520 –0.513 – –0.551	"Milk Quality Regulation" *(Milch-Güte-Verordnung)* local German quality regulations Sienkiewicz and Kirst, 2006
dry matter	%	≈ 13.00	Frister, 2007
dry matter free of fat	%	≥ 8.50	local German quality regulations
density	g/ml g/cm³	≥ 1.028 1.027–1.032	EU regulation 1234/2007 Sienkiewicz and Kirst, 2006
pH	–/–	6.4–6.7	Sienkiewicz and Kirst, 2006
SH (titratable acidity)	°SH	6.0–7.5	Kiermeier and Lechner, 1973; Sienkiewicz and Kirst, 2006
alkaline phosphatase	pos./neg.	neg.	Sienkiewicz and Kirst, 2006
peroxydase	pos./neg.	pos. (TP)/neg. (ESL, UHT)	Sienkiewicz and Kirst, 2006
lactose	%	4.5–5.2	Sienkiewicz and Kirst, 2006
calcium	%	0.12–0.14	Frister, 2007; Sienkiewicz and Kirst, 2006

1234/2007 (3.50 %). Although the German "milk and fat law" *(Milch- und Fettgesetz)* claims 3.00 % as the minimum, commercial milks usually contain < 0.3, 1.5, 3.5 % fat. Recently, other fat contents like 1.8 % or a "natural fat content" have been introduced into the market. From a legal point of view, the lack of fat could be interpreted as an attempt of deceit. As this statement originates from a non-governmental institution, the German law offers the option of issuing a so-called "entitlement of correct use" *(Berechtigungsanfrage)* which eventually may lead to official reprimands (Weyland, 2008). However, caution must prevail as the analysis method used is focused on raw milk, and heat-processed milk may react differently during infrared spectroscopy. For irrefutable results, the official reference method L01.00-9 (i. e. DIN EN ISO 1211) should be applied. Slight differences between spectroscopy and the reference method have been described (Kylä-Siurola and Antila, 1983), so that this apparent lack of fat is rated as of minor concern.

The acidity parameters (pH and SH) usually react complementarily; based on low initial total bacterial count (data not shown here), bacteria usually acidify the milk during storage leading to a decreased pH and increased SH values. This is seen markedly in the UHT milk (Tab. 4). However, changes in SH were much stronger that those in pH; this is due to the fact that titratable acidity registers the milks' potential to buffer rather than representing the concentration of H^+ ions. In the case of TP, shelf life was too short to affect SH values significantly which must be considered as a sign of quality. With regard to titratable acidity in ESL milk, values ranged markedly below the customary and even decreased towards the end of shelf life, while pH reacted inversely. Titratable acidity values are mainly influenced by casein (2/5 of the original acidity), by minerals (2/5 of the original acidity) and by secondary phosphate-mediated reactions ("over-run"; 1/5 of the original acidity) as well as by the content of acids, specifically by lactic acid (Montuoro, 2006). Changes in dry matter observed in ESL affect none of those factors, and so they may be attributed to the thermal processes the milk is submitted to. Heating is known to affect titratable acidity in a peculiar manner as temperatures of up to 150 °C decrease it because of the elimination of CO_2 from the milk. Higher temperatures however increase it because of molecular changes and acid formation because of lactose degradation. Furthermore, temperature also affects the solubility of calcium phosphate, but this effect is reversible once the milk cools down (Kiermeier and Lechner, 1973). Many ESL milks are produced via infusion with culinary steam, a procedure which is thought to eliminate more gas from the milk. This method is a direct heating procedure rather than an indirect one (e. g. by a plate heater), and if the latter is the case, SH values resemble those of UHT milks (Sepúlveda et al., 2005). ESL acidity data in Tab. 4 do not resemble those for UHT, so it is suggested that this particular behaviour of the parameter is due to technological reasons.

All in all however, all variables did not show any major concerns so that quality of the products throughout the shelf life can be testified. The results also showed that each fluid milk type represents an individual product. As to the freshness debate, all milks were fresh at the beginning of shelf life, and TP and ESL milks remained so to the end of it. The question however is if this "freshness" of the ESL milk samples is truly due to gentle treatment or to some other technological procedure which creates a similar effect.

3.4 Sensory evaluation

Of the auditorium, n = 45 persons participated voluntarily as panellists. Milk samples were served at 16 ± 2 °C. A total of 67 % (30 panellists) detected the ESL milk sample as the one that was different from the other two samples. 18 % and 16 % of votes claimed either of the two TP samples to be different from the rest. The level of significance α amounted to 0.001, i. e. the test persons detected a significant difference in taste between TP and ESL milks.

Consumers rank sensory properties first (cited in Westermair, 2008). The literature claims that there were no or little differences in taste between TP and ESL milks (Lehmann, 2009, Kaufmann et al., 2009, 2010). Gallmann et al. (2001) claimed that consumers could hardly tell TP from ESL milk, but if they did, they ranked ESL between TP and UHT. The results of the present survey however showed that consumers were indeed capable of differentiating between TP and ESL. Although this sensory analysis was merely triangle test-based, a previous study performed under due conditions (Grabowski et al., 2013) reached similar conclusions, with 80 % of panellists that were able to differentiate between TP and ESL milk. These differences may be explained by the fact that ESL milk may be manufactured in many different ways, and Rademacher and Hülsen (2005) found that sensory results varied with the kind of ESL process, and that the taste of HTT milk was closer to UHT than it was to TP milk. Micro filtrated ESL milks are said to taste similarly to TP milk, although in some process varieties, this milk tends to absorb a papery taste from the package. These authors however used a different sensory test (a modified version of IDF standard 99C:1997).

Flavour and flavour changes in processed milk are the result of a very complex interaction of the milk components among themselves and with their environment. Heat treat-

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ment-induced and storage time-induced changes include caramelisation and hydroxymethyfurfural in lactose, Maillard reaction and "cooking flavour" in proteins as well as liberation of free fatty acids, lipolysis and rancid flavours in milk fat. Absorption of other flavours may occur when milk gets in contact with other substances, e. g. packaging material. Some off-flavours occur intrinsically, others are mediated by the presence of light and/or oxygen. Besides that, other process steps (e. g. pressure application) may also change the sensory experience by promoting the formation of volatile components such as hydrogen sulphide or aldehydes (Schmidt and Renner, 1978, Santos et al., 2003, Van Ardt et al., 2005, Vázquez Valverde et al., 2006).

Regarding taste and flavour, literature has commenced to group ESL milks into filtration/pasteurization milks and HTT milks; they may be differentiated readily by the peroxidase test (Gallmann et al., 2001).

4 Conclusion

The present study showed that although composition of TP, ESL (HTT) and UHT milk met all standards, ESL milk turned out to be a product that was 'different' in taste and composition from the other milks, especially from TP.

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