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Goat sweet whey quality – chemical composition and microbiological status

Qualität von Ziegen-Süßmolke – Chemische Zusammensetzung und mikrobiologischer Status

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Summary

Goat whey is a by-product from the cheese production and contains lactose, as well as easily digestible whey proteins. Goat whey has not been used intensively for human consumption yet. This study delivers data about the chemical composition and microbiological status of goat sweet whey originating from soft cheese produced by a German medium-sized cheese factory. 24 samples were analysed for total solids, fat, lactose and protein between May 2013 and April 2014. The total bacterial count and the counts of lactic acid bacteria of 44 samples taken from April 2013 to August 2014 were examined. Further, selected samples were tested for pseudomonads, yeasts, moulds and enterobacteria.

The mean value of protein was 0.9 %, fat 0.4 %, lactose 3.9 % and total solids 6.2 %. The average total bacterial count of the native whey was 6.9 $\log_{10}$ cfu/ml with a majority formed by lactic acid bacteria and *Penicillium camemberti* added for cheese production after the milk pasteurisation. Enterobacteria, yeasts and pseudomonads were also discovered. Lactose and proteins were found in consistently high amounts with slight variations only. The results show that strict hygiene protocols applied during production would enable an acceptable microbiological whey quality. The utilisation of goat whey for human consumption is desirable.

Keywords: lactic acid bacteria, moulds, pseudomonads, fat, protein, lactose

Zusammenfassung

Ziegenmolke entsteht als Nebenprodukt bei der Käseherstellung. Sie enthält Laktose und leicht verdauliches Molkenprotein, wurde aber bisher kaum für die menschliche Ernährung genutzt. Ziel der Studie war es, Daten über die chemische Zusammensetzung und mikrobiologische Qualität von Ziegen-Süßmolke, die bei der Herstellung von Weichkäse in einer deutschen mittelgroßen Käserei anfiel, zu erfassen. Von Mai 2013 bis April 2014 wurden 24 Proben auf den Trockenmasse-, Fett-, Laktose- und Proteingehalt untersucht. Im Zeitraum von April 2013 bis August 2014 wurden von 44 Proben die Gesamt- und Milchsäurebakterienkeimzahl sowie von ausgewählten Proben die Keimzahlen von Pseudomonaden, Hefen, Schimmelpilzen und Enterobakterien ermittelt.

Folgende durchschnittliche Gehalte wurden ermittelt: Protein: 0,9 %, Fett: 0,4 %, Laktose: 3,9 % und Trockenmasse: 6,2 %. Die mittlere Gesamtkeimzahl der nativen Molke betrug 6,9 $\log_{10}$ KbE/ml, wobei den größten Anteil die für die Käseherstellung der Milch zugegebenen Milchsäurebakterien und *Penicillium camemberti* ausmachten. Außerdem wurden Enterobakterien, Hefen und Pseudomonaden festgestellt. Der Laktose- und Proteingehalt war abgesehen von geringfügigen Schwankungen immer gleich hoch. Die Ergebnisse zeigen, dass mit strikten Hygienemaßnahmen während des Produktionsprozesses eine mikrobiologisch akzeptable Molke hergestellt werden kann. Eine Nutzung von Ziegenmolke für die menschliche Ernährung ist anzustreben.

Schlüsselwörter: Milchsäurebakterien, Schimmelpilze, Pseudomonaden, Fett, Protein, Laktose

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Introduction

In Germany, the importance of goat husbandry and goat products is minor compared to other European countries especially in the Mediterranean region (le Jaouen and Toussaint, 1993; von Korn et al., 2013). However, the goat population has increased from 1980 to 2005 by about 60 % (Kengeter, 2003; von Korn et al., 2013). The currently estimated goat population in Germany is 117 000–130 200 (FAO, 2016; Statistisches Bundesamt, 2013). Approximately half of them, kept especially in the Southern German federal states (Bayern, Baden-Württemberg) and in Saxony (Kengeter, 2003; von Korn et al., 2013), are used for dairy production (von Korn, personal communication). Commonly used breeds include „Bunte Deutsche Edelziege“ (about 70 %) and „Weiße Deutsche Edelziege“ (about 25 %) (Kengeter, 2003; Jendretzke, 2009).

Goat's milk products are enjoying growing popularity in Germany as an alternative for people suffering from cow's milk allergies (Park, 1994; Kengeter, 2003), because of an increasing interest in organic (Pandya and Ghodke, 2007) and gourmet products (Kengeter, 2003; von Korn et al., 2013) as well as due to an influx of immigrants from Southern and Eastern European Countries who prefer goat's milk (Kengeter, 2003).

36 000 t goat's milk and 3 000 t goat's cheese are annually produced in Germany (von Korn et al., 2013). Whey is a by-product of cheese production. Approximately 80 to 90 % of the milk volume accumulates as cheese whey (González-Martínez et al., 2002; Kaur et al., 2009; Moreno-Indias et al., 2009; Tranjan et al., 2009). The nutritional value and the digestibility of whey are high. Only few publications about goat whey are available, however, literature about the physiological impact of whey does not deal particularly with goat whey but with similar biological values of cow whey. Goat whey assumptions were merely extrapolated from the findings. Normally, whey contains about 50 % of the milk solids (González-Martínez et al, 2002; Jeličić et al., 2008). The main constituent of whey is lactose, a favourable substrate for the gastro-intestinal microflora (Shendurse et al., 2009), which stimulates intestinal peristalsis and is a valuable source of energy (Jeličić et al., 2008). Additionally, whey proteins are valuable nutrients, which contain essential amino acids in high quantities (Sienkiewicz and Riedel, 1986; Barth and Behnke, 1997). One and a half liter of whey meets the daily requirements of essential amino acids (Jeličić et al., 2008). Furthermore, minerals such as calcium, phosphorus, potassium and sodium, a favourable calcium: phosphorus-ratio (Barth and Behnke, 1997) and vitamins, especially B-vitamins are present in whey (Vojnović et al., 1993; Barth and Behnke, 1997; Djurić et al., 2004). Proven antibacterial properties, for instance against *Listeria monocytogenes* (Almaas et al., 2008) were described by Barth and Behnke (1997) and Jeličić et al. (2008), appetite restraining properties (Zafar et al., 2013), and anti-hypertensive effects (Barth and Behnke, 1997; Fluegel et al., 2010) were also documented. Despite the valuable properties described above, goat whey has been neglected as a consumer product. Possible incorporation into beverages and dietary products (Casper et al., 1998; Moreno-Indias et al., 2009; Tranjan et al., 2009), as it is currently the case with cow whey (Holsinger et al., 1974; Sienkiewicz and Riedel, 1986; Barth and Behnke, 1997; Jeličić et. al., 2008), could become a viable future option. Numerous investigations are necessary to ensure safe and palatable products. Therefore, chemical and microbiological data are generated in this study.

Materials and methods

Sample-taking

The study was conducted in cooperation with a medium sized cheese factory processing goat's milk from five regional farms in which goat breeds “Bunte Deutsche Edelziege” and “Weiße Deutsche Edelziege” are kept. Cheese whey originated from goat milk pasteurised at 72 °C for one second. After pasteurisation rennet, thermophilic and mesophilic lactic acid bacteria as well as *Penicillium candidum*-cultures as commercial starter cultures were added for the production of soft cheeses. 24 and 44 cheese whey samples were taken from the factory for chemical and microbiological analysis, respectively, half an hour after cutting the curd. Each sample (800 ml) was filled into sterile plastic bottles and transported in a cooling box and if not immediately examined, stored in a fridge at 4 °C.

Physico-chemical examination

24 samples were evaluated twofold for protein, fat, lactose and total solids content in the course of the year from May 2013 to April 2014 based on DIN- and ISO-standards. Protein was determined by Kjehldahl-Method (Kjehldahl-therm KB; titrator Vapodest 50 C. Gerhardt GmbH & Co. KG, DE) (DIN EN ISO, 2002). Fat contents were measured by means of the Weibull-Berntropp-Method (DIN, 1992). The extraction was carried out using a Soxtherm-extraction-unit (C. Gerhardt GmbH & Co. KG, DE).

Lactose was determined using a test kit of R-biopharm and measured spectrophotometrically using the photometer Spekol 1200 (Analytik Jena AG, DE) (DIN, 1982). Total solids contents were analysed according to dry-oven-method outlined in DIN-standards (DIN, 1988) using FD 240 (BINDER GmbH, DE). The pH-value of each sample was measured by the means of a pH-Meter pH 340i (WTW GmbH, DE) and the electrode Sentix 61 (WTW GmbH, DE). In addition, the acidity was titrated with 0.25 molar sodium hydroxide solution (Honeywell Specialty Chemicals Seelze GmbH/ Riedel de Haën, DE) according to national DIN method (DIN, 2000).

Microbiological examination

Total bacterial count in goat's cheese whey was tested as well as for the bacterial counts of lactobacilli, yeasts/moulds, pseudomonads and enterobacteria by the surface plating technique in the course of 16 months from April 2013 to August 2014. In total 44 samples were analysed within 24 hours of sample taking. The following culture media were used: Plate-count-skim-milk-agar (PCM) for the total bacterial count, incubation 30 °C for 72 hours (ISO, 2013); deMan, Rogosa and Sharpe-Agar (MRS), modified pH-value 6.5 for lactic acid bacteria, incubation 37 °C for 72 hours (ISO, 1998); Yeast-Extract-Glucose-Chloramphenicol-Agar (YGC) for yeasts and moulds, incubation 25 °C for 96 hours (DIN, 2005); Cetrimid-Fucidin-Cephalothin-Agar (CFC) for pseudomonads, incubation 25 °C for 48 hours, (VDLUFA, 1993) and Violet-Red-Bile-Dextrose-Agar (VRBD) for enterobacteria using surface plating technique instead of pour plate method, incubation 37 °C, 18 hours (DIN ISO, 2009). 100 µl of suspension were applied on each of two plates for every dilution stage (detection limit <10 cfu/ml). Additionally, one millilitre of

undiluted whey was spread on three plates for the investigation of enterobacteria, pseudomonads and yeasts to reach a detection limit of 1 cfu/ml. Gram stain assay, oxidase and catalase test were used to characterise the grown colonies.

The species of the genus *Pseudomonas* were further defined by biochemical reactions using the Api 20 NE test (bioMérieux Deutschland GmbH, DE).

Statistical evaluation

The data were tested for Pearson-correlations, normal distribution and significant differences in the course of the investigation period by the IBM SPSS Statistics 22 program. A significance level of 0.05 was assessed. Furthermore, it was tested whether climate or the daylight length influenced the chemical and microbiological results (Anonymus, 2014a; Anonymus, 2014b). Relevant changes compared to the remaining period were determined by the T-Test for independent samples concerning normal distributed parameters and by the Whitney-U-Test concerning not normal distributed parameters (total solids, protein and total bacterial count).

Results

Physico-chemical examination

The average pH-value of the samples was 6.7 with variations from 5.9 to 7.4, the average acidity was 4.7 °SH with variations from 2.4 to 9.8 °SH.

Table 1 shows the results of the chemical analysis of goat's cheese whey. Significant correlations between total solids and protein and lactose contents, respectively, were evident ($r_{TS+Pr.} = 0.499$, $p < 0.05$; $r_{TS+L} = 0.521$, $p < 0.01$). Fat and total solid contents correlated slightly negatively with the outer temperature ($r_{fat+temp.} = 0.442$, $p < 0.05$; $r_{TS+temp.} = 0.435$, $p < 0.05$).

Fat content showed significant higher values in the winter and early spring months (December to March) compared to the rest of the year ($t = 3.536$, $p < 0.01$). However, no climatic or seasonal influences on protein and lactose contents were detectable.

Microbiological examination

Arithmetic average of logarithmised bacterial counts (results below the detection limit not respected), minima, maxima and standard deviations are presented in Table 2. Lactic acid bacteria were the dominant flora as a consequence of a starter cultures added at the beginning of the cheese-making process. The main part of the grown colonies on YGC-agar consisted of *Penicillium* spp. (2.7 $\log_{10}$ cfu/ml), also added as starter cultures to the milk. Twenty samples contained yeasts (mean value of 1.8 $\log_{10}$ cfu/ml). In the first days of sampling yeasts were overgrown by moulds and not countable. Pseudomonads were detected in 30 of 40 samples with a mean value of 2.4 $\log_{10}$ cfu/ml. In two whey samples, they were by the means of Api 20 NE identified as *Pseudomonas fluorescens, Pseudomonas aeruginosa* and *Pseudomonas luteola.*

TABLE 1: *Results of chemical analysis of goat cheese whey.*

(g/100 ml)	Average Value	Minimum	Maximum	Relative SD
Protein	0.9	0.3	1.2	0.20
Fat	0.4	0.3	0.7	0.23
Lactose	3.9	1.8	4.7	0.16
Total solids	6.2	2.0	8.8	0.19

SD: Standard Deviation

TABLE 2: *Microbiological results of goat cheese whey, n = 44.*

$\log_{10}$ cfu/ml	Average	Minimum	Maximum	SD
Total bacterial count[1]	6.9	4.9	8.7	1.0
Lactic acid bacteria[2]	6.9	4.0	8.7	1.1
Pseudomonads[3]	2.4	none	5.0	1.0
Enterobacteria[4]	2.5	none	5.2	1.0
Yeasts[5]	1.8	none	4.5	1.2

cfu: colony forming unit; none: not detected in 1 ml; SD: Standard Deviation; Arithmetic average values of logarithmised bacterial counts (values below detection limit not respected); analysed samples/samples > detection limit (1, 2) 44/44, (3) 40/30, (4) 42/39, (5) 41/20

The bacterial counts showed high variations in the course of the year, which are summarised in the Figures 1 to 4. The counts of pseudomonads, enterobacteria and yeasts were above the average on two days (2013-11-12, 2014-03-12), of enterobacteria and yeasts on three days (2014-01-22, 2014-06-26, 2014-07-30) and of pseudomonads and enterobacteria on eight days (2013-04-23, 2013-05-08, 2013-06-25, 2013-10-22, 2013-12-03, 2014-02-04, 2014-02-26, 2014-06-11). In addition, the bacterial counts of enterobacteria, pseudomonads and yeasts showed significant correlations ($r_{pseudomonads+enterobacteria} = 0.441$, $p < 0.01$; $r_{pseudomonads+yeasts} = 0.360$, $p < 0.05$; $r_{enterobacteria+yeasts} = 0.969$, $p < 0.01$).

Discussion

The physico-chemical results concerning pH-values were in the expected range (Casper et al., 1998; Tranjan et al., 2009).

Casper et al. (1998) studied the average chemical composition of goat sweet whey in an eight-month period.

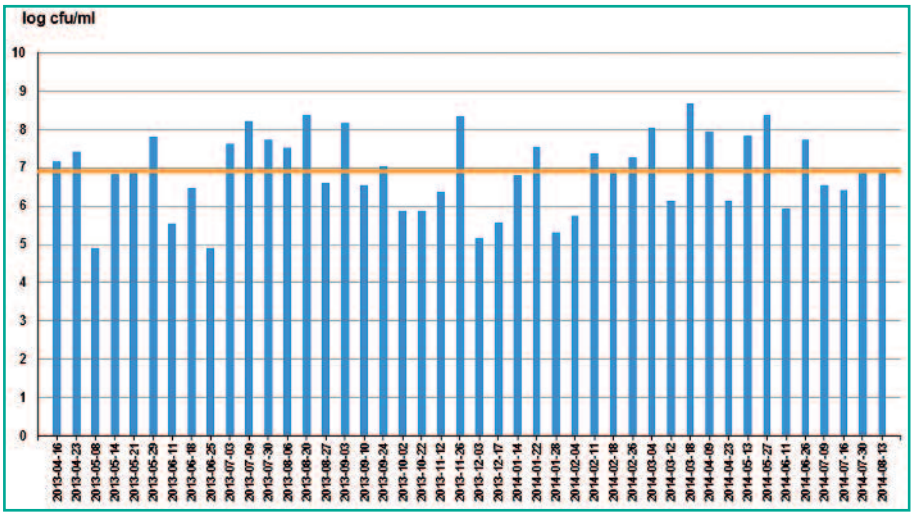

FIGURE 1: *Total bacterial count (corresponded to lactic acid bacteria), orange line: arithmetic mean value 6.9 $\log_{10}$ cfu/ml, x-axis: date of sampling (n = 44).*

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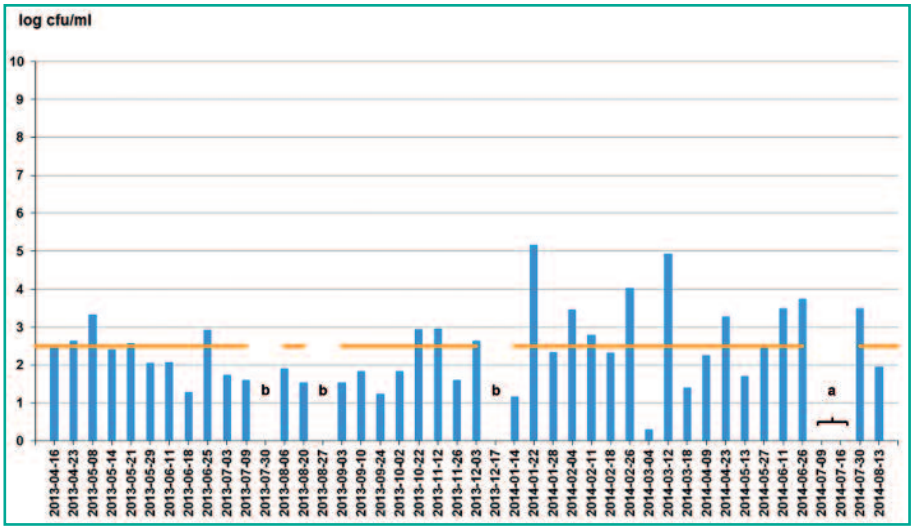

FIGURE 2: *Enterobacteria, orange line: arithmetic mean value 2.5 log_{10} cfu/ml (n = 39), x-axis: date of sampling (n = 42), a: not done, b: enterobacteria not detected in 1 ml.*

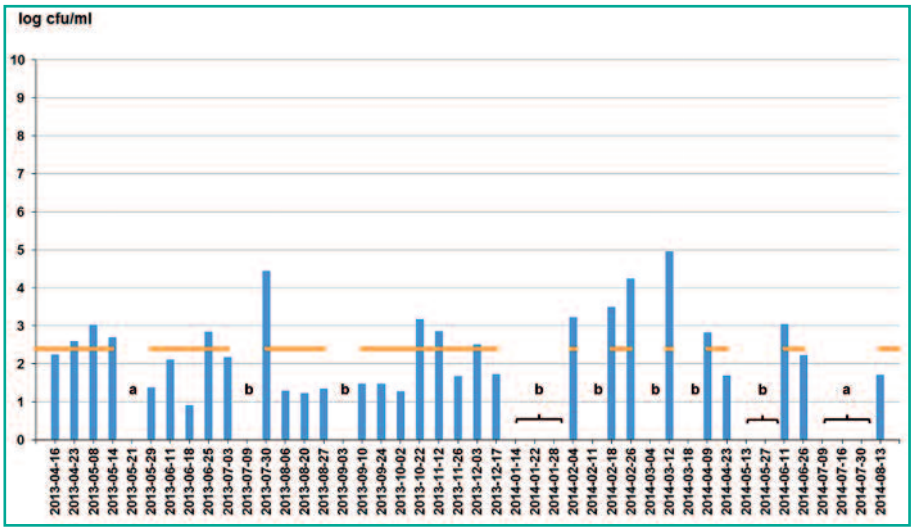

FIGURE 3: *Pseudomonads, orange line: arithmetic mean value 2.4 log_{10} cfu/ml (n = 30), x-axis: date of sampling (n = 40), a: not done, b: pseudomonads not detected in 1 ml.*

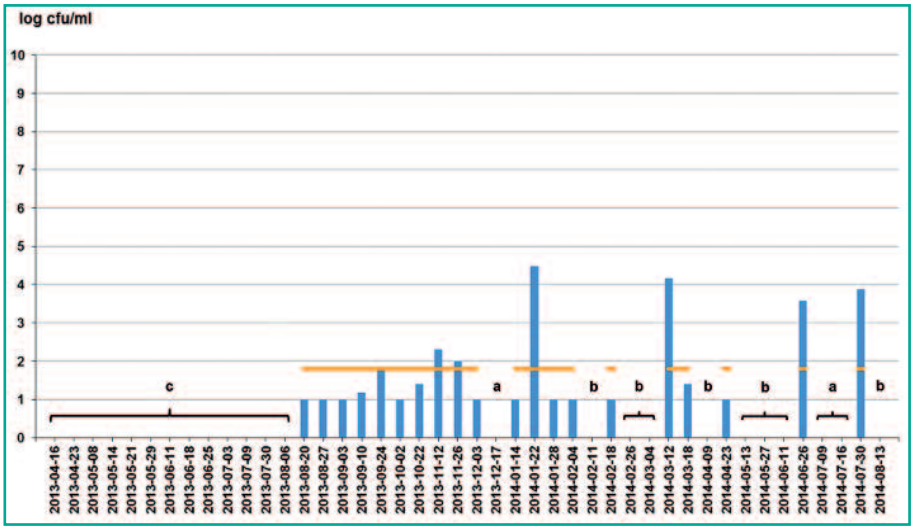

FIGURE 4: *Yeasts, orange line: arithmetic mean value 1.8 log_{10} cfu/ml (n = 20), x-axis: date of sampling (n = 41), a: not done, b: yeasts not detected in 1 ml, c: not countable.*

The lactose content was 4.71, protein 0.77 and fat 0.51 %. The lactose value was about one percent higher, fat slightly higher and total protein slightly lower compared to our results (lactose: 3.9, fat: 0.4, protein: 0.9 %). Sert and Akin (2013) who compared goat, sheep and cow cheese whey of the Turkish cheese Tulum found average values of goat whey to have 0.4 % higher fat, 0.25 % higher protein and more than 1 % higher total solid content compared to our data (total solids: 6.2 %). Tranjan et al. (2009) developed goat whey beverages flavoured with strawberry and peach pulp. Fat and protein values of the whey beverages were similar to the plain, non-flavoured whey in our study. Beverages contained much higher total solids values likely resulting from pulp contents. Moreno-Indias et al. (2009) analysed eighty goat whey samples and observed significant differences between fat content of goat whey produced on farms and in cheese factories depending on the effectiveness of curd fat recovery from cheese. In our study, fat contents were similar to values observed in the farm produced whey (approximately 0.7 %). Total solids varied between the different whey producing technologies (approximately 7.06 and 5.08 %). The concentration of lactose was roughly one percent higher with farm production (approximately 4.9 %) but comparable with cheese factory production. Protein content was slightly lower (by 0.1 %) compared to our results.

Compared to whey of other animal species, the nutrient values of cow whey were similar to the whey data generated in this study (Kosikowski and Masters, 1984; Sienkiewicz and Riedel, 1986; Barth and Behnke, 1997; Casper et al., 1998; Jeličić et al., 2008; Baldissera et al., 2011; Sert and Akin, 2013). Lira et al. (2009) recorded slightly higher protein (1.19 %) and much higher fat (1.2 %) and lactose (5.84 %) values in untreated buffalo whey because buffalo milk naturally contains higher concentrations of these nutrients. Sheep whey showed generally higher lactose, protein and fat contents, too (Casper et al., 1998; Sert and Akin, 2013), which is correlated to the higher values in sheep milk (Flamant and Morand-Fehr, 1982; Jandal, 1996; Casper et al., 1998; Pandya and Ghodke, 2007).

Finally, results of this study compared with published data show that

goat whey varies in the concentration of the main components (protein, lactose and fat). This is mainly influenced by milk composition (Casper et al., 1998), which is dependent upon breed, feeding, stage of lactation and climate (Haenlein, 1996). Furthermore, cheese processing technology and the type of processed cheese have an effect of whey composition. Rudovsky (2008) reported the highest fat and protein contents in the goat milk before kidding which normally takes place in the spring months. However, we can confirm an influence of the kidding time only for the fat values which were significant higher from January to March.

The microbiological examination in this study showed average values of 6.9 $\log_{10}$ cfu/ml lactic acid bacteria, 2.4 $\log_{10}$ cfu/ml pseudomonads, 2.5 $\log_{10}$ cfu/ml enterobacteria, 2.9 $\log_{10}$ cfu/ml yeasts and moulds and a total bacterial count of 6.9 $\log_{10}$ cfu/ml (7.9 x 10^6 cfu/ml). Sert and Akin (2013) compared Tulum cheese whey made of raw goat's, sheep's and cow's milk, respectively, and reported that Tulum goat's cheese whey showed the highest total bacterial count with a value of 6.05 $\log_{10}$ cfu/g compared to cow and sheep whey with 5.24 and 5.68 $\log_{10}$ cfu/g, respectively, that means approximately one log-level lower compared to our data. On the other hand, much higher counts (6.16 $\log_{10}$ cfu/ml) of yeasts and moulds were observed in this non-heated goat whey. The total bacterial count in whey of heated milk and the estimated count of yeasts and moulds were much lower than in our study because no starter cultures for cheese production were used. Lira et al. (2009) recorded an aerobic mesophilic bacterial count of 1.8 x 10^4 cfu/ml of buffalo sweet whey made of pasteurised milk, which is much lower than in our study, probably due to the fact that the whey contains no added starter cultures. The average total bacterial count of mesophilic bacteria in our goat whey was slightly higher than in the study described by Cortez et al. (2013) (6.16 $\log_{10}$ cfu/ml) and Merin (1986) (3.4 x 10^6 cfu/ml) for cow sweet whey. In our study, yeasts, pseudomonads and enterobacteria were not detected in the pasteurised raw milk in any case (data not shown). On the other hand, enterobacteria and pseudomonads were observed in the whey, which suggests recontamination during cheese production. Teixeira et al. (2007) estimated an average psychrotrophic bacterial count of 10^2 to 10^3 cfu/ml in cow whey. Higher counts of psychrotrophic bacteria (5.32 $\log_{10}$ cfu/ml) were reported by Cortez et al. (2013). Both research groups explained the detection of psychrotrophic bacteria by recontamination of whey during the production process. In our study, pseudomonads which belong to the group of psychrotrophic bacteria were observed in 30 of 40 samples. An investigation of all process steps showed that pseudomonads were distributed in the water system. After disinfection of the system, the pseudomonads were not detectable in whey. A direct comparison of the microbiological data is difficult due to different cheese types and production processes. Detailed information about the technologies used was not documented in the available literature.

Results of this study show that goat's cheese whey is a valuable resource for the human food chain. Lactose and proteins were found in consistently high amounts with slight variations only. Furthermore, whey fulfills the criteria for a low fat product. Conclusions drawn from our microbiological data suggest that consistent and strict hygiene protocols applied during production would reduce the risk of whey recontamination, guaranteeing a product that is safe and of high quality.

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Conflict of interest

We certify that there is no actual or potential conflict of interest in relation to this article.

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