Heliyon 10 (2024) e40717

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Effects of Sichuan pepper (*Zanthoxylum bungeanum*) and cumin (*Cuminum cyminum* L.) on the quality and antioxidant capacity of Camembert type cheese made from goat milk

Solomon Gebereyowhans [a,*], Shuwen Zhang [b], Xiaoyang Pang [b], Kidane Workelul [b], Jing Lu [b], Jiaping Lv [b]

[a] *Tigray Agricultural Research Institute, Mekelle, Ethiopia*
[b] *Key Laboratory of Agro-Food Processing and Quality Control, Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences, Beijing, 100193, PR China*

ARTICLE INFO

Keywords:
Camembert type cheese
Cheese quality
Cheese texture
Goat milk
Spices

ABSTRACT

The study was carried out to determine the effects of addition of Cumin (Cuminum cyminum L.), Sichuan pepper (Zanthoxylum bungeanum) or their mixture on the chemical, textural, microbial and sensory characteristics and antioxidant capacity of Camembert type cheese made from dairy goats. The chemical composition of cheese was not affected by addition of spices (Cumin, Sichuan pepper or their mixture). Addition of spices considerably affected the texture, microbial and sensory quality and antioxidant capacity of cheese. Overall acceptability score increased from 2.8 in the control cheese to 3.7, 3.2 and 3.4 in the cheeses spiced with cumin, Sichuan pepper and their mixture, respectively after 40 days of ripening. All spiced cheeses also showed higher antioxidant activity compared to the control cheese. Total phenolic content increased from 20.8 to 82.3 in the control cheese to 32.5–94.5, 46.7–118.8, 37.4–104.6 in the cheeses spiced with cumin, Sichuan pepper and their mixture, respectively during the 40 days of ripening period. Similarly, the DPPH increased from 10.4 to 60.4 in the control cheese to 16.7–73.5, 25.8–87.8, 20.3–80.7 in the cheeses spiced with cumin, Sichuan pepper and their mixture, respectively during the 40 days of ripening period. In conclusion, addition of Cumin, Sichuan pepper and their mixture produced goat milk camembert type cheese with better sensory quality and antioxidant capacity without affecting the composition of cheese.

1. Introduction

Cheese is among the different dairy products produced worldwide with a better shelf life and significant nutritional and health benefits [1]. Nutrients such as essential amino acids, fatty acids, protein, bioactive peptides, minerals, fat and vitamins are abundant in cheese [1–3]. Cheese has a global consumption and has long been a vital part of human nutrition. Worldwide, several cheese types with different physico-chemical and sensory properties have been reported so far [4].

Camembert is one of the most well-known cheese varieties that comes from a small French village of Camembert in the Normandy region. The fungus *Penicillium camemberti* utterly covers the cheese's surface and gives its distinctive flavor and aroma as well as its

* Corresponding author. Mekelle, Ethiopia.
E-mail address: sgg1976bd@gmail.com (S. Gebereyowhans).

https://doi.org/10.1016/j.heliyon.2024.e40717
Received 4 February 2024; Received in revised form 15 November 2024; Accepted 25 November 2024
Available online 27 November 2024

white appearance [5]. Camembert cheese has a relatively short ripening time, high nutritional value and wider consumption [6]. Though Camembert cheese was traditionally manufactured from cow milk, currently, cheesemakers can produce it from the milk of dairy sheep and goats [2,7].

Nowadays, because of their distinctive flavor, nutritional value and curative characteristics, goat milk and its cheese have become an active area of research in dairy science. Compared to cow milk and its various cheese varieties, goat milk and its cheese are known to be advantageous in human nutrition due to their superior nutritional and therapeutic characteristics [2,8]. Because of its smaller fat globule size, goat milk and its cheese are better in digestibility, and proteins in goat milk are also high in biological value and less in allergenic potential [9]. Furthermore, goat milk and its cheese are rich in healthy fatty acids (e.g *conjugated linoleic acid*), minerals (Mg, Fe, Ca and Zn) and vitamins (A and B complexes) [2,10].

Though there is sufficient information related to the importance of dairy products obtained from goat milk, the availability of goaty flavor in goat milk and its cheese, caused by the higher concentrations of short-chain fatty acids, particularly C6:0, C8:0 and C10:0, negatively affects their preference by consumers [2,10]. In this perspective, developing a novel goat milk cheese would be necessary to increase goat milk cheese consumption, and use of spices is a vital approach to add flavor and enhance novelty to the cheese as it attracts customers who might not otherwise want to eat goat milk cheese because of its goaty taste. Increasing the demand for cheese with the addition of spices may potentially present the dairy industry with a viable and appealing chance to grow its market. In several earlier studies, different spices were used in various types of cheeses primarily made from cow milk to confer varieties of flavors and make the cheese more preferable by consumers [11–13]. Nowadays, in addition to improving the flavor, addition of spices could improve the functional properties of the cheese by enhancing its antioxidant capacity [14,15].

Cumin (Cuminum cyminum L.), an annual plant native to the Mediterranean region and a member of the Umbelliferae family, is one of the most widely used spices. Cumin seeds, both in whole and/or ground forms, have been commonly used in many different food preparations since ancient times. Cumin seeds provide additional taste and flavor to foods. In addition to food flavoring, recently, other functional activities of cumin such as antimicrobial and antioxidant activities have been extensively reported [16–18].

Sichuan pepper (Zanthoxylum bungeanum), known as Huajiao in China, also belongs to the Rutaceae family and is native to Sichuan, Guanxi, Yunnan, Tibet, Guizhou and Guandong provinces of China [19]. The fruit of Sichuan pepper and their pericarps are mainly used as spice in various Chinese dishes, particularly in Sichuan province, due to their unique taste known as “ma” (a pungent taste) [20]. In recent years, in addition to its importance as a spices to enhance the flavor of foods, Sichuan pepper displayed marked antibacterial and antioxidant activities [21]. Despite application of different spices to cow milk cheese improved the sensory and microbial quality as well as the antioxidant capacity, to the authors’ knowledge, there is limited data related to applications of spices (cumin and Sichuan pepper) in Camembert type cheese, particularly, made from goat milk. Thus, the objective of present study was to evaluate how cumin, Sichuan pepper and their mixture affect the physicochemical, sensory and microbial quality and antioxidant capacity of Camembert type cheese made from goat milk.

2. Materials and methods

This experiment was carried out at the dairy processing pilot in the Institute of Food Science and Technology, Beijing, China. The goat milk used in this experiment was collected from a private farm located in Shanxi province, China. The flavoring spices (Cumin and Sichuan pepper), commercially prepared in the form of powder, were also purchased from a private supermarket in Beijing.

2.1. Manufacture of Camembert type cheese

Four types of Camembert type cheeses were manufactured in duplicate at two different times, and the cheeses manufactured were: Cheese spiced with cumin (*Cuminum cyminum* L.), cheese spiced with Sichuan pepper (*Zanthoxylum bungeanum*), cheese spiced with mixture of cumin and Sichuan pepper (at 1:1 ratio) and cheese with no spice. Cheeses were produced as outlined by Lee and Bae [22,23] with slight modifications. In summary, the milk underwent pasteurization at 65 °C for a duration of 30 min. Afterward, it was cooled to 35 °C and combined with starter culture (R-707 DVS, *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *cremoris*: 3.5 g/100 kg), 0.02 % CaCl2 (w/v) (30 mL/100 kg), and 1 g of spice per kg of milk were added to each cheese vat, mixed thoroughly to ensure uniform distribution of spices, and allowed to rest for 60 min. Subsequently, 0.9 g/100 kg of rennet (Chy-Max Powder Extra NB, 2235IMCU/mL, Chr.Hansen A/S, Hoersholm, Denmark) was incorporated into each cheese vat and maintained for 60 min. Following 60 min of coagulation, the curd was sliced into 16 mm cubes, agitated at 35 °C for 10 min, and then let to sit for 15 min. Approximately 40 % of the whey was removed, and the curd was placed into the mold. The curd was stored at room temperature for 22 h, being flipped frequently. Following production, the cheese samples were immersed in a 20 % (w/w) brine solution for 20 min at 20 °C. One hour post-brining, P. Camemberti (0.03 g/100 kg) was diluted and applied by spraying onto the cheese surfaces. The cheeses were stored in a ripening chamber at 13 °C and 94 % relative humidity for a duration of 14 days [5]. Cheeses were being turned every two days. On day 14, the cheeses were encased in a reference wrap and kept at 4 °C for a duration of 40 days.

2.2. Chemical analysis

Cheeses samples at 1, 14, 27 and 40 days of ripening were obtained to evaluate the trend of physicochemical properties. The moisture content was determined based on the AOAC method 935.42 [24]. Cheese samples were dried in an oven at 105 °C until a stable weight was achieved. Protein was determined based on AOAC method 920.123 [24], and total protein was calculated using a conversion factor of 6.8. Fat was quantified in accordance with AOAC Method 933.05 [24]. Ash content was determined following

AOAC Method 920.153 [24] by burning the cheese sample in a muffle furnace at 550 °C for 4 h.

2.3. Texture profile analysis (TPA)

The texture characteristics of the cheese samples were assessed using the TA-HD plus texture analyzer (Stable Micro Systems Ltd., Godalming, UK). Cylindrical cheese samples (2 cm in diameter and 1.5 cm in height) were created to obtain three replicates for each sample. A 2-bit compression test was conducted on the cheese samples with a 36 mm diameter aluminum cylindrical probe (P-36). The testing speed was established at 2 mm/s, and the cheese samples were pressed down to 75 % of their initial height [10].

2.4. Microbial analysis using 16 S rRNA gene amplicon sequencing

The total microbial DNA was isolated based on the work of Barzideh et al. [25] and refined using E.Z.N.A stool DNA kit (Omega Biotek, Norcross, US). To magnify the V3-V4 hypervariable region of the 16S rRNA gene, the primers 341F 5′-CCTACGGGNGGCWGCAG-3′ and 806R 5-GGACTACHVGGGT ATCTAAT-3′ were employed. The PCR reaction mixture included 4 μl of 10× KOD buffer, 1.5 μl of KOD polymerase, 4 μl of 2 mM dNTPs, 2 μl of each primer (5 μM), along with 150 ng of microbial DNA. The amplification process began with denaturation at 95 °C for 2 min, then followed by 27 cycles consisting of 98 °C for 10 s, annealing at 62 °C for 30 s, and then extended at 68 °C for 30 s; with a final extension at 68 °C for 10 min. The amplicons were measured and processed for paired-end sequencing (2 × 250) using the Illumina MiSeq platform (Illumina, San Diego, California). Reads containing over 10 % unknown nucleotides and those with less than 80 % of bases having a quality value greater than 20 were discarded to achieve high-quality sequencing reads. Hereinafter, valid reads were obtained by removing the chimeric tags and the UPARSE pipeline [26] was used to cluster the valid reads into the operational taxonomic units (OTUs) at 97 % similarity. According to the SILVA database for *16 S rRNA* gene sequencing [27], OTUs were classified into organisms using RDP classifier [28].

2.5. Antioxidant assays

2.5.1. Preparation of Camembert type cheese extracts

Extracts of Camembert type cheese were prepared according to the work of Hell et al. [1,29] with slight modifications. In summary, 20 g of the cheese sample was mixed with 100 mL of ultrapure water and vortexed for 30 min at room temperature. Hereinafter, the suspension was incubated at 37 °C for 1 h, after which the mixture was centrifuged at 3000×*g* for 30 min at 4 °C. Thereafter, the supernatant was subjected to filtration through filter paper (Whatman No. 1) and finished with a 0.45 μm syringe filter.

2.5.2. Determination of total phenolic content

The total phenolic content of the extract was measured using the Folin–Ciocalteu method as outlined by Lee and Bae [22,23]. Briefly, 0.5 mL of the extract was added to a test tube and mixed well for 3 min with 0.5 mL of 95 % ethanol and 3 mL of distilled water. To every sample, 0.5 mL of Folin-Ciocalteu reagent (50 %; v/v) was incorporated and mixed; then, 1.0 mL of 5 % Na2CO3 was added. Subsequently, the mixture was permitted to sit in the dark for 60 min, after which the absorbance was recorded at 725 nm (Spectrophotometer, Optizen 1412V, Korea). Standard curves were created using various concentrations of gallic acid (Sigma-Aldrich, USA). The standard curve was used to calculate total phenolic content, expressed as microgram equivalents of gallic acid per gram of the sample.

2.5.3. Determination of 2,2-diphenyl-1- picryl-hydrazyl (DPPH) radical scavenging ability

The DPPH radical scavenging activity was determined based on the work of Lee and Bae [22,23] Briefly, 250 μL of the extract was added to 3 mL of 60 μM DPPH in ethanol. Hereinafter, absorbance was measured at 517 nm and the readings were then compared with the control that contained 250 μL of water instead of the extract. Finally, the % inhibition was calculated as follows:

$$\%\ \text{inhibition} = [(\text{control} - \text{extract}) / \text{control})] \times 100$$

2.6. Sensory analysis

Sensory analysis was assessed after 14 and 40 days of ripening as outlined by Sant'Ana et al. [10] and Sicard et al. [5]. Samples were evaluated by a panel containing 30 assessors. Assessors were chosen based on their cheese-eating experience from staff members of the Institute of Food Science and Technology and the Institute of Animal Science, Chinese Academy of Agricultural Sciences. Cheese samples were characterized based on *Penicillium camemberti* coverage, color, odor, taste and texture. The Consumer assessment was performed using a hedonic scale from 1 to 5 (1 = dislike severely, 2 = dislike a little, 3 = neither like nor dislike, 4 = like a bit, and 5 = like very much).

For every cheese, a 30 g sample was put on small white plates marked with random 3-digit codes and presented to each assessor at room temperature. The assessors cleaned their palates with low-salt crackers and water between each sample evaluation.

2.7. Statistical analysis

A split plot design was used to assess the effects of spices addition (cheeses; spiced with cumin, spiced with Sichuan pepper, spiced with mixture and non-spiced cheese), ripening duration and their interaction on the response variables recorded at ripening time intervals. A general linear model (GLM) procedure from the SAS program (version 9.1) was employed to conduct the analysis of variance (ANOVA). Tukey's test was used to separate treatment means and a statistically significant difference was accepted at $P < 0.05$.

3. Results and discussion

3.1. Chemical properties

The use of spices did not influence the moisture, protein, fat, and ash levels in goat milk Camembert type cheese (Table 1). However, the contents of protein, moisture, fat and ash were affected by maturation time. The similarities in contents of moisture, fat, protein and ash observed in this study were in line with the findings of Krumov et al. [30] who reported similar contents of moisture, protein, fat and ash between spiced and non-spiced processed cheeses during ripening. Furthermore, Zantar et al. [31] reported insignificant difference in those parameters between *Thymus vulgaris* or *Origanum compactum* spiced and non-spiced goat milk fresh cheese during storage. As ripening advanced, moisture levels decreased, which can be assumed to result from the evaporation of moisture and volatile compounds from the cheese surface. Our findings have been supported by Mei et al. [32] and Lee and Bae [27] who noted a reduction in moisture level of Camembert type cheese during the ripening process. Unlike moisture, the contents of protein, fat and ash increased as maturation time increased. The increase in protein, fat and ash contents during ripening could be explained by the reduction in moisture content during ripening [30].

3.2. Texture profile

The texture parameter values for both spiced and non-spiced goat milk Camembert type cheese during ripening are shown in Fig. 1. The inclusion of spice and the duration of ripening influenced ($P < 0.05$) hardness (Fig. 1a). After 14, 27 and 40 days of ripening, cheeses spiced with Sichuan pepper were harder than the non-spiced cheese, whereas the cheese spiced with cumin and blends of cumin and Sichuan pepper showed an intermediate hardness. The difference in hardness among the various cheese types may be due to the difference in the influence of the incorporated spices on the microbial activity which is vital to the degradation of caseins in cheese [33]. As indicated in the microbial analysis section of this study, the abundance of genus *Lactococcus* that was added as a starter culture during cheese manufacturing, a vital for the degradation of caseins during cheese ripening, was lower in cheese samples spiced with Sichuan pepper. Licón et al. [34] reported higher hardness in ewe milk cheese when saffron is added to the cheese. Furthermore, Tarakç and Deveci [35] reported lower hardness for control white cow milk cheese particularly compared to cheeses spiced with mint, whereas cheeses spiced with thyme and black cumin, showed intermediate hardness which is in accordance with the observations of our study.

As ripening advanced, a reduction in hardness was noted, and all cheeses exhibited less hardness by the end of the ripening period (Fig. 1a). Previously, several authors [36,37] reported reduction in hardness as ripening time increased. The reduction in hardness of all cheeses throughout ripening may be linked to the softening of the cheese structure resulted from elevated proteolysis [38], pH [39] and solubilization of colloidal calcium phosphate [40].

Adhesiveness, cohesiveness and springiness were not affected by spices addition, whereas ripening time affected ($P < 0.05$) those parameters. Cheese composition is an important factor in influencing those parameters [41]; thus the similarity in adhesiveness, cohesiveness and springiness observed among the cheese types in this study may be linked to their similarity in composition. As

Table 1
Chemical properties of goat milk Camembert type cheeses spiced with cumin, Sichuan pepper and their mixture.

Parameters	Days	Treatments			
		Control	Cumin	S. pepper	Mixture
Moisture (%)	1	51.87 ± 0.29^{A}	52.06 ± 0.89^{A}	52.90 ± 0.15^{A}	53.12 ± 0.16^{A}
	14	50.66 ± 0.74^{AB}	50.53 ± 0.58^{AB}	50.83 ± 0.30^{B}	51.65 ± 0.51^{AB}
	27	49.25 ± 0.92^{BC}	49.01 ± 0.11^{B}	49.64 ± 0.05^{B}	50.04 ± 0.17^{BC}
	40	48.15 ± 0.22^{C}	47.99 ± 0.78^{B}	48.28 ± 0.54^{C}	48.99 ± 0.95^{C}
Protein (%)	1	18.74 ± 0.91^{C}	18.92 ± 0.08^{C}	18.22 ± 0.32^{C}	18.78 ± 0.24^{D}
	14	20.25 ± 0.18^{B}	20.63 ± 0.38^{B}	20.68 ± 0.12^{B}	20.37 ± 0.21^{C}
	27	21.64 ± 0.58^{AB}	21.28 ± 0.44^{B}	21.48 ± 0.39^{B}	21.51 ± 0.16^{B}
	40	22.28 ± 0.26^{A}	22.15 ± 0.17^{A}	22.44 ± 0.35^{A}	22.12 ± 0.04^{A}
Fat (%)	1	24.47 ± 0.24^{B}	24.95 ± 0.15^{B}	24.65 ± 0.12^{B}	24.70 ± 0.58^{B}
	14	25.48 ± 0.35^{AB}	25.61 ± 0.35^{B}	25.43 ± 0.62^{AB}	25.34 ± 0.68^{AB}
	27	25.64 ± 0.49^{AB}	25.71 ± 0.23^{B}	25.57 ± 1.64^{AB}	25.70 ± 1.54^{AB}
	40	26.08 ± 0.18^{A}	26.64 ± 0.11^{A}	26.52 ± 0.61^{A}	26.86 ± 0.42^{A}
Ash (%)	1	2.42 ± 0.02^{B}	2.47 ± 0.01^{B}	2.23 ± 0.01^{B}	2.20 ± 0.18^{B}
	14	2.55 ± 0.03^{B}	2.59 ± 0.10^{AB}	2.42 ± 0.15^{AB}	2.38 ± 0.01^{AB}
	27	2.62 ± 0.05^{AB}	2.70 ± 0.02^{AB}	2.54 ± 0.08^{AB}	2.49 ± 0.10^{AB}
	40	2.70 ± 0.12^{A}	2.82 ± 0.16^{A}	2.63 ± 0.07^{A}	2.63 ± 0.12^{A}

$^{A–C}$ Different capital superscript letters within a column denote differences ($P < 0.05$) between different days of ripening.

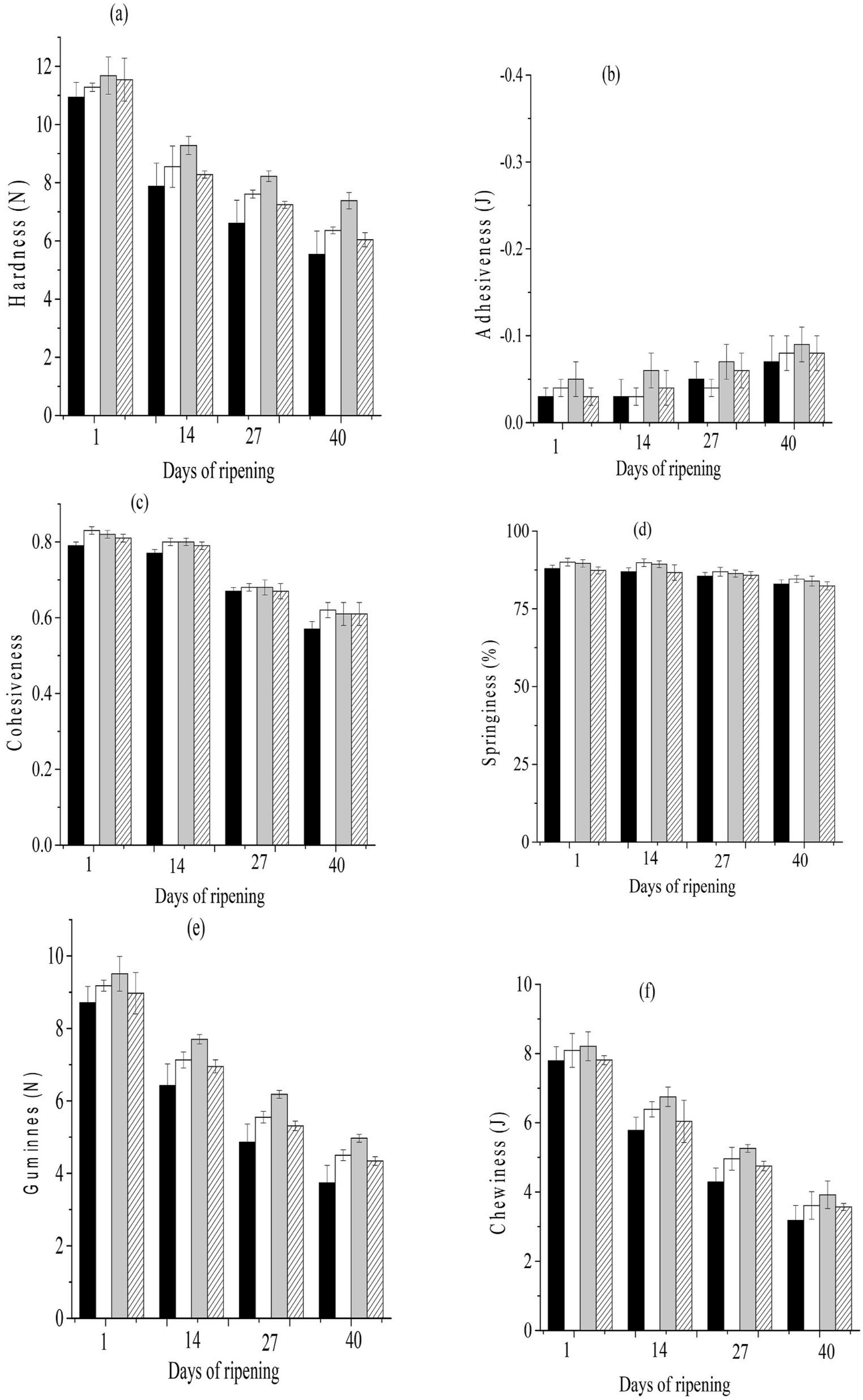

Fig. 1. Texture profile of Camembert cheese made from control (■) spiced with cumin (□), spiced with Sichuan pepper (■) and spiced with cumin and Sichuan pepper mixture (▨).

ripening progressed, the values for those parameters were low after 40 days of ripening, particularly in comparison to the initial ripening period (Fig. 1b, c and 1d). Zheng et al. [41] found a positive association between the moisture content of cheese and all these parameters, aligning with the low moisture content noted in the final ripening stage of this study. Our results are also in agreement with the findings of [35] who reported similarity in those parameters among cheeses spiced with different spices but increased as ripening time progressed. As gumminess and chewiness are derived from hardness, both followed similar trends with hardness (Fig. 1e and f) which was also linked with the results of Mahgoub et al. [42] and Sant'Ana et al. [10] who observed similar trends for those parameters with hardness.

3.3. Microbial abundance and diversity

Taking into account the communities from all samples, a total of 999 OTUs were detected, of which 537 were categorized at genus level. As expected the genus Lactococcus remained abundant in all cheese samples throughout ripening because the species *Lactococcus lactis* was added as a starter culture during cheese manufacturing. Compared to the other cheese types, cheeses spiced with Sichuan pepper had lower abundance of genus Lactococcus throughout ripening (Fig. 2). The overall average of genus Lactococcus accounted for 74.88 %, 73.30 % 71.16 % and 65.03 % of the total genera in the control, mixture spiced, cumin spiced and Sichuan pepper spiced cheeses, respectively. In an earlier study by Shin and Kim [43], Sichuan pepper showed higher antimicrobial activity compared to cumin. Thus, the difference in the abundance of genus Lactococcus among spiced cheeses of the present study could be due to the difference in antimicrobial activity, particularly genus Lactococcus, of cumin and Sichuan pepper. Previously, several authors [44–46] reported that the microbial composition of different types of cheeses and other dairy products were predominantly composed of lactic acid bacteria, particularily from the genus *Lactococcus* and *Streptococcus*. These bacterial groups are often mixed with the starting milk as starter culture during cheese manufacturing and contribute to enhance the flavor and texture of various cheese varieties due to their important role in fat and protein metabolism [47]. Next to genus Lactococcus, all cheeses were predominated with *Macrococcus*, *Rothia*, *Lactobacillus*, *Pseudomonas*, *Massilia* and *Streptococcus*, indicating similar dominance of microbes with slight differences. For instance, spicing Camembert cheese with Cumin and Sichuan pepper slightly decreased the relative abundance of *Pseudomonas* and *Lactobacillus* (Fig. 2).

Diversity indices (Chao1, PD whole tree, and Shannon) significantly varied among cheeses and repining time (Fig. 3). Overall, during the first 27 days of ripening, cheese spiced with Sichuan pepper showed higher diversity compared to the other types of cheeses. Forty days after maturation, cheeses spiced with cumin and Sichuan pepper had higher diversity than that of control cheese and cheese spiced with their mixture. Diversity is expected to be lower while the microbial community is dominated by a single or few species (Marino et al., 2017). The higher diversity observed for the cheese spiced with Sichuan pepper during ripening may be associated with the lower abundance of Lactococcus observed in the cheeses samples spiced with Sichuan pepper during ripening compared to the other cheese types. Our observation is in accordance with the observations of Akarca et al. (2016) who noted variations in microbial diversity as a result of species application in Mozzarella cheese made from cow milk.

3.4. Antioxidant analysis

All samples of spiced Camembert type cheese exhibited greater ($P < 0.05$) total phenolic content than the control Camembert type cheese samples (Table 2). The higher amounts of total phenolic contents observed in the spiced Camembert type cheese samples of our study could be due to the high concentrations of polyphenols in cumin and Sichuan pepper [48,49]. The results also indicated that the type of spice greatly affected the total phenolic content of goat milk Camembert type cheese, that is, cheese samples spiced with Sichuan pepper showed higher total phenolic content compared to cheese samples spiced with cumin, whereas, cheese samples spiced

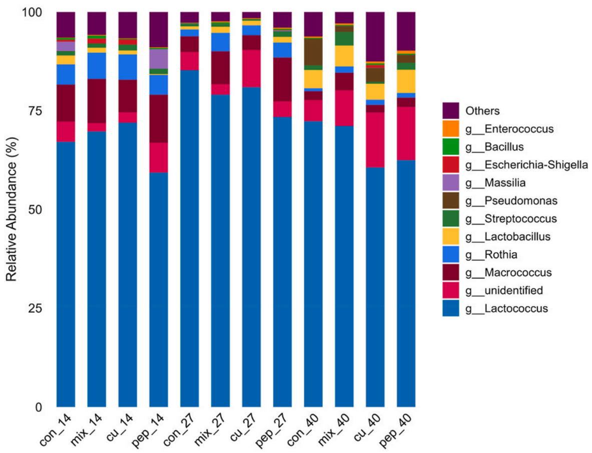

Fig. 2. Microbial composition of goat milk Camembert cheese spiced with cumin, Sichuan pepper and their mixture.

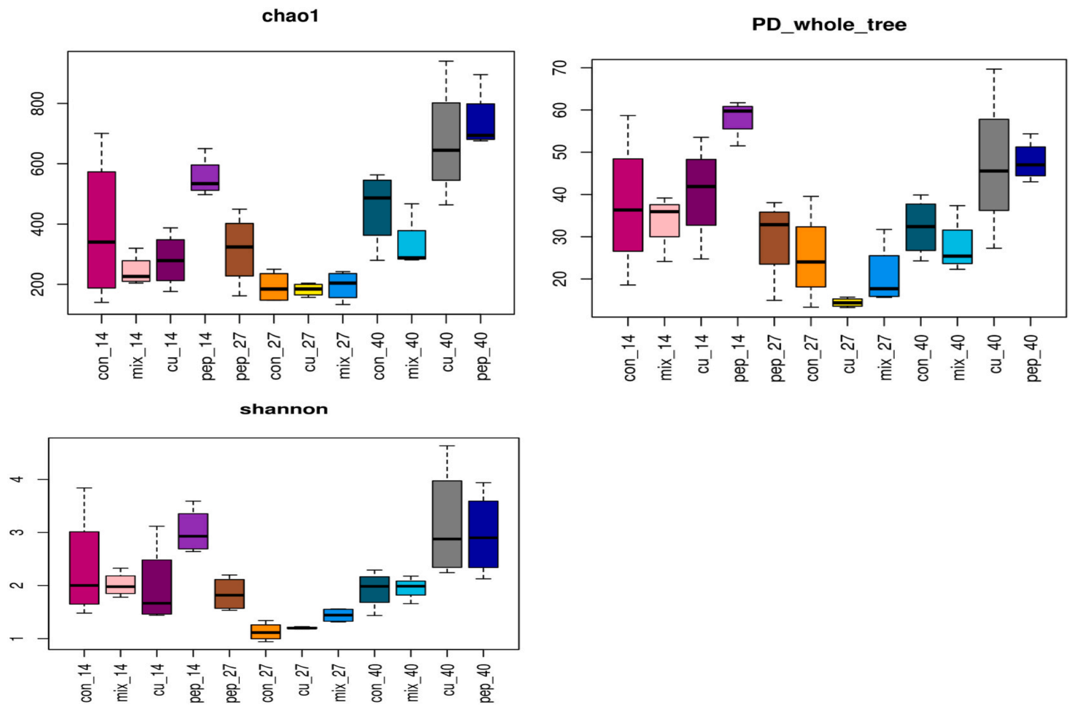

Fig. 3. Microbial diversity indices (Chao1, PD_whole_tree and Shannon) of goat milk Camembert type cheese spiced with cumin, Sichuan pepper and their mixture.

Table 2
Total phenolic content (mg GAE/g of sample) and DPPH (% of inhibition) of goat milk Camembert cheese spiced with cumin, Sichuan pepper and their mixture.

Parameters	Days	Treatments			
		Control	Cumin	S. pepper	Mixture
Phenolic content	1	20.8 ± 1.3^{cA}	32.5 ± 0.8^{bA}	46.7 ± 1.6^{aA}	37.4 ± 2.1^{abA}
	14	55.2 ± 2.0^{cB}	67.9 ± 1.6^{bB}	85.7 ± 1.8^{aB}	74.4 ± 1.4^{abB}
	27	76.3 ± 2.3^{cC}	88.6 ± 2.2^{bC}	107.6 ± 2.1^{aC}	98.6 ± 1.5^{abC}
	40	82.3 ± 1.2^{cC}	94.5 ± 0.9^{abC}	118.8 ± 1.4^{aD}	104.6 ± 0.8^{abC}
DPPH	1	10.4 ± 0.8^{cA}	16.7 ± 0.9^{bA}	25.8 ± 1.2^{aA}	20.3 ± 0.8^{bA}
	14	43.5 ± 2.0^{cB}	56.4 ± 1.8^{bB}	69.7 ± 2.1^{aB}	63.2 ± 1.5^{abB}
	27	56.3 ± 1.5^{cC}	67.3 ± 1.8^{bC}	80.6 ± 2.0^{aC}	74.5 ± 1.9^{abC}
	40	60.4 ± 1.4^{cC}	73.5 ± 1.5^{bC}	87.8 ± 1.3^{aC}	80.7 ± 2.0^{abC}

a–c Different lowercase superscript letters within a row denote differences ($P < 0.05$) between treatments.
A–D Different capital superscript letters within a column denote differences ($P < 0.05$) between different days of ripening.

with the mixture of cumin and Sichuan pepper showed intermediate values (Table 2). The difference in total phenolic content observed among the spiced Camembert type cheese samples may be explained by the difference in the amounts of polyphenols between the spices. For instance, Lu et al. [50] reported higher total phenolic content in Sichuan pepper (38.86 mg GAE/g dry weight) compared to cumin (9.00 mg GAE/g dry weight). Similar to our findings, Weragama et al. [51] reported a greated total phenolic content in spiced cream cheese. Additionally, Yerlikaya et al. [15] reported higher phenolic content in Mozzarella cheese when spices such as rosemary, basil, peppermint and Turkish oregano were incorporated in the cheese.

Based on the DPPH assay results, all the spiced Camembert type cheese samples showed markedly greater ($P < 0.05$) DPPH values than the control cheese sample (Table 2). The higher DPPH values of the spiced Camembert cheeses observed in this study may be linked to the potential DPPH free radical scavenging activity of cumin and Sichuan pepper as previous studies reported high DPPH free radical scavenging activity for cumin [52] and Sichuan pepper [19,50]. Concerning the spice type, the findings revealed that the spice variety had a considerable impact on the DPPH values of goat milk Camembert type cheese. Specifically, cheese samples spiced with Sichuan pepper exhibited greater DPPH values than those spiced with cumin, while cheese samples spiced with both cumin and Sichuan pepper demonstrated intermediate levels (Table 2). The variation in DPPH observed in the spiced Camembert cheese samples might result from the difference in DPPH levels in cumin and Sichuan pepper. For instance, Lu et al. [50] reported a greater DPPH levels in Sichuan pepper (inhibition %, 93.41) compared to Cumin (inhibition %, 18.12). To the best of our observation, despite there was no study carried out regarding the addition of Sichuan pepper to cheese so far, studies [11,53] carried out on the addition of cumin to cheese showed an increase in antioxidant activity that agreed with our observation.

As ripening advanced, a notable rise in DPPH level was shown in every type of cheese (Table 2). Higher DPPH level was displayed during the last stages of ripening compared to the initial stage of ripening. In different cheese types, DPPH shows the existence of various peptides. During cheese ripening, various peptides can be formed as a result of proteolysis; and these peptides not only play an important role in the improvement of flavor and texture but also have a noticiable functional value [54]. A study by Hernández-Galán et al. [55] was conducted to determine the antioxidant properties of peptides obtained from Mexican Cotija hard cheese ripened for six months and the HPLC characterization showed a positive relationship between the antioxidant properties of the cheese and peptides. In the present study, the texture profile analysis result showed an increase in cheese softening during the propagation of ripening; this may also indicate an increase in proteolysis. Thus, the higher DPPH level observed during ripening in the current study could be due to the formation of various peptides during the propagation of cheese ripening.

3.5. Sensory analysis

The sensory analysis values after 14 and 40 days of ripening for goat milk Camembert type cheese spiced with cumin, Sichuan pepper and their mixtures are presented in Fig. 4(a) and (b), respectively. Significant variation in sensory characteristics was observed among cheeses. During both ripening times evaluated, cheese with no spice application had lower values for odor, taste and overall acceptability, whereas the value for color preference was higher for the control cheese. Regarding the spiced cheeses, a significant variation was not observed in overall acceptability, odor and taste. Sichuan pepper is rich in aroma compounds such as linalool, eucalyptol, α-terpineol, geraniol and Hydroxyl-α-sanshool which are considered as primary odor and taste contributors [56]. Similarly, cumin is rich in aroma compounds such as cumin aldehyde, cuminic alcohol, cymene and terpenoids which are considered as primary odor and taste contributors [57]. Thus, the higher scores for odor, taste and overall acceptability of the spiced cheeses could be associated with the availability of these aroma compounds in the spiced cheeses. Our observation was similar to the observations of Krumov et al. [30] and Seifu [58] who reported higher scores for taste, odor and overall acceptance of processed cheeses and Metata ayib (a fermented traditional Ethiopian cottage cheese) produced using spices.

Penicillium coverage and texture did not vary significantly among cheeses during both ripening times. This observation was also in line with the observations of Licón et al. [34] and Tarakçı and Deveci [35] who noted similar texture between spiced and non-spiced cheeses. Except for texture, the other attributes were not affected by ripening time. As ripening progressed, scores for texture decreased for all cheeses which could be attributed to the availability of runny edges during the last stage of ripening. Furthermore, Licón et al. [34] and Tarakçı and Deveci [35]reported a decrease in texture preference of spiced and non-spiced cheeses during the last stage of

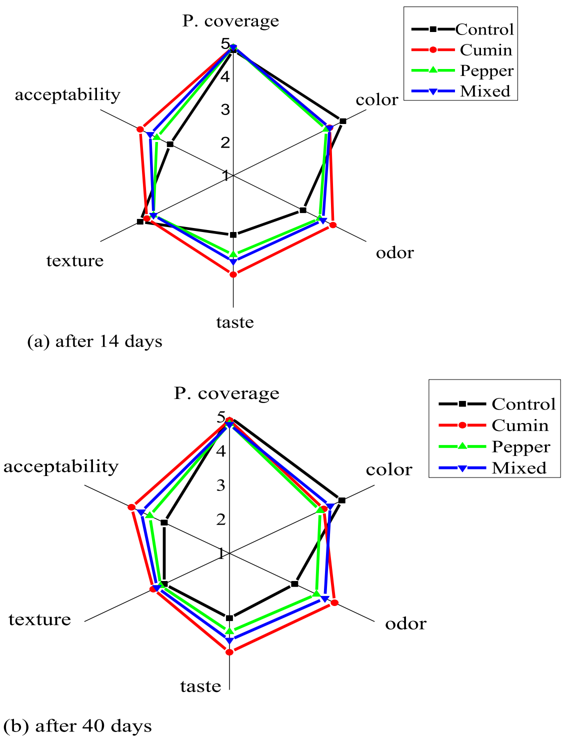

Fig. 4. Sensory properties of goat milk Camembert type cheese spiced with cumin, Sichuan pepper and their mixture during 14 and 40 days of ripening.

ripening which are both similar to the present observation.

4. Conclusion

This study demonstrated that goat milk Camembert type cheese with Cumin and Sichuan pepper is a new alternative product with promising potential. Addition of Cumin, Sichuan pepper or their mixture had positive effects on the sensory characteristics and antioxidant capacity of goat milk Camembert type cheese without affecting its compositional properties. Though all spiced cheeses showed considerable antioxidant potential, cheeses spiced with Sichuan pepper exhibited higher antioxidant capacity. Hence, these new varieties of goat milk Camembert type cheeses will present new choices for consumers looking for new tastes and functional values.

CRediT authorship contribution statement

Solomon Gebereyowhans: Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shuwen Zhang:** Software, Methodology, Formal analysis. **Xiaoyang Pang:** Writing – review & editing, Writing – original draft, Visualization. **Kidane Workelul:** Writing – review & editing, Methodology. **Jing Lu:** Writing – review & editing, Methodology, Formal analysis. **Jiaping Lv:** Writing – review & editing, Supervision, Methodology, Formal analysis.

Ethical statement

The sensory evaluation was covered by a general approval from the human ethics committee at the Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences. All participants gave informed written consent. The study did not need formal ethical approval by the National Committee on Health Research Ethics. Consumers in the present study participated voluntarily and received no compensation.

Data and code availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Solomon Gebreyowhans reports equipment, drugs, or supplies was provided by Chinese Academy of Agricultural Sciences Institute of Food Science and Technology. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Tigray Agricultural Research Institute, Ethiopia and the Innovation Programme of Chinese Academy of Agricultural Sciences for supporting laboratory facilities during the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e40717.

References

[1] A. Hell, S. Labrie, L. Beaulieu, Effect of seaweed flakes addition on the development of bioactivities in functional Camembert-type cheese, Int. J. Food Sci. Technol. 53 (2018) 1054–1064, https://doi.org/10.1111/ijfs.13681.

[2] S. Gebreyowhans, S. Zhang, X. Pang, B. Yang, T. Wang, Z. Wu, Changes in texture, composition and sensory characteristics of Camembert cheese made from a mixture of goat milk and cow milk during ripening, Int. J. Dairy Technol. 73 (2020) 1–12, https://doi.org/10.1111/1471-0307.12699.

[3] S. Niro, M. Succi, P. Tremonte, E. Sorrentino, R. Coppola, G. Panfili, A. Fratianni, Evolution of free amino acids during ripening of Caciocavallo cheeses made with different milks, J. Dairy Sci. 100 (2017) 9521–9531, https://doi.org/10.3168/jds.2017-13308.

[4] D.L. Borneman, S.A. Rankin, A comparison of fresh, pasta filata, and aged Hispanic cheeses using sensory, chemical, functional, and microbiological assessments, J. Dairy Sci. 99 (2016) 1–14, https://doi.org/10.3168/jds.2015-10112.

[5] M. Sicard, N. Perrot, I.C. Trelea, D. Picque, G. Corrieu, Temperature and relative humidity influence the ripening descriptors of Camembert-type cheeses throughout ripening, J. Dairy Sci. 98 (2015) 1325–1335, https://doi.org/10.3168/jds.2014-8916.

[6] D. Batty, J.G. Waite-Cusic, L. Meunier-Goddik, Influence of cheese-making recipes on the composition and characteristics of Camembert-type cheese, J. Dairy Sci. 102 (2019) 164–176, https://doi.org/10.3168/jds.2018-14964.

[7] T. Voblikova, A. Permyakov, A. Rostova, G. Masyutina, A. Eliseeva, Influence of the maturation process on the sheep's milk of Camembert cheese fatty acid profile change, KnE Life Sci. (2020) 696–705, https://doi.org/10.18502/kls.v5i1.6153.

[8] A.K. Yadav, J. Singh, S.K. Yadav, Composition, nutritional and therapeutic values of goat milk : a review, Asian J. Dairy Food Res. 35 (2016) 96–102, https://doi.org/10.18805/ajdfr.v35i2.10719.
[9] S. Kashyap, N. Shivakumar, V. Sejian, N.E.P. Deutz, T. Preston, S. Sreeman, S. Devi, A.V. Kurpad, Goat milk protein digestibility in relation to intestinal function, Am. J. Clin. Nutr. 113 (2021) 845–853, https://doi.org/10.1093/ajcn/nqaa400.
[10] A.M.S. Sant'Ana, F.F. Bezerril, M.S. Madruga, A.S.M. Batista, M. Magnani, E.L. Souza, R.C.R.E. Queiroga, Nutritional and sensory characteristics of Minas fresh cheese made with goat milk, cow milk, or a mixture of both, J. Dairy Sci. 96 (2013) 7442–7453, https://doi.org/10.3168/jds.2013-6915.
[11] T.M.M.A. El gabali, O.A.M. Jadain, I.E.M. El Zubeir, Effect of addition of Syrian thyme (Thymus syriacus) on physiochemical and sensory quality of Sudanese Mudaffara cheese during storage, J. Food Sci. Technol. 60 (2023) 517–527, https://doi.org/10.1007/s13197-022-05634-7.
[12] R. Josipović, Z.M. Knežević, J. Frece, K. Markov, S. Kazazić, J. Mrvčić, Improved properties and microbiological safety of novel cottage cheese containing spices, Food Technol. Biotechnol. 53 (2015) 454–462, https://doi.org/10.17113/ftb.53.04.15.4029.
[13] D. Weragama, V. Weerasingha, L. Jayasumana, J. Adikari, J.K. Vidanarachchi, H. Priyashantha, The physicochemical, microbiological, and organoleptic properties and antioxidant activities of cream cheeses fortified with dried curry leaves (Murraya koenigii L.) powder, Food Sci. Hum. Wellness 9 (2021) 5774–5784, https://doi.org/10.1002/fsn3.2551.
[14] A. Shaukat, M. Nadeem, T.M. Qureshi, R. Kanwal, M. Sultan, O.B. Kashongwe, R.R. Shamshiri, M.A. Murtaza, Effect of in vitro digestion on the antioxidant and angiotensin-converting enzyme inhibitory potential of Buffalo milk processed cheddar cheese, Foods 10 (2021) 1–16, https://doi.org/10.3390/foods10071661.
[15] O. Yerlikaya, E. Akan, O.Y. Bayram, A.D. Karaman, O. Kinik, The impact of medicinal and aromatic plant addition on antioxidant, total phenolic, antimicrobial activities, and microbiological quality of Mozzarella cheese, Int. Food Res. J. 28 (2021) 508–516, https://doi.org/10.47836/ifrj.28.3.10.
[16] G. Ghasemi, M. Fattahi, A. Alirezalu, Y. Ghosta, Antioxidant and antifungal activities of a new chemovar of cumin (Cuminum cyminum L.), Food Sci. Biotechnol. 28 (2019) 669–677, https://doi.org/10.1007/s10068-018-0506-y.
[17] F.S. Mohammed, M. Sevindik, İ. Uysal, C. Çesko, H. Koraqi, Chemical composition, biological activities, uses, nutritional and mineral contents of cumin (Cuminum cyminum), Meas, Food 14 (2024) 14–19, https://doi.org/10.1016/j.meafoo.2024.100157.
[18] B. Alizadeh Behbahani, M. Noshad, F. Falah, Cumin essential oil: phytochemical analysis, antimicrobial activity and investigation of its mechanism of action through scanning electron microscopy, Microb. Pathog. 136 (2019) 103716, https://doi.org/10.1016/j.micpath.2019.103716.
[19] Y. Zhang, Z. Luo, D. Wang, F. He, D. Li, Phytochemical profiles and antioxidant and antimicrobial activities of the leaves of zanthoxylum bungeanum, Sci. World J. 2014 (2014) 1–13, https://doi.org/10.1155/2014/181072.
[20] K. Zhong, X. Li, A. Gou, Y. Huang, Q. Bu, H. Gao, Antioxidant and cytoprotective activities of flavonoid glycosides-rich extract from the leaves of Zanthoxylum bungeanum, J. Food Nutr. Res. 2 (2014) 349–356, https://doi.org/10.12691/jfnr-2-7-4.
[21] L. Xia, J. You, G. Li, Compositional and antioxidant activity analysis of Zanthoxylum bungeanum seed oil obtained by supercritical CO 2 fluid extraction, J. Am. Oil Chem. Soc. 88 (2011) 23–32, https://doi.org/10.1007/s11746-010-1644-4.
[22] J. Lee, I. Bae, Quality characteristics, changes in physiochemical properties and functional properties of camembert cheese containing red ginseng powder, Korean J. Food Sci. Anim. Resour. 38 (2018) 64–77, https://doi.org/10.5851/kosfa.2018.38.1.64.
[23] J.S. Lee, I. Bae, Quality characteristics, changes in physiochemical properties and functional properties of camembert cheese containing red ginseng powder, Korean J. Food Sci. Anim. Resour. 38 (2018) 64–77, https://doi.org/10.5851/kosfa.2018.38.1.64.
[24] AOAC International, Official methods of analysis, in: AOAC Int., seventeenth ed., AOAC International, Gaithersburg, 2000, pp. 5–15.
[25] Z. Barzideh, M. Siddiqi, H.M. Mohamed, G. LaPointe, Dynamics of starter and non-starter lactic acid bacteria populations in long-ripened cheddar cheese using Propidium monoazide (PMA) treatment, Microorganisms 10 (2022) 1–24, https://doi.org/10.3390/microorganisms10081669.
[26] R.C. Edgar, UPARSE: highly accurate OTU sequences from microbial amplicon reads, Nat. Methods 10 (2013) 996–998, https://doi.org/10.1038/nmeth.2604.
[27] E. Pruesse, C. Quast, K. Knittel, B.M. Fuchs, W. Ludwig, J. Peplies, F.O. Glöckner, SILVA: a comprehensive online resource for quality checked and aligned ribosomal RNA sequence data compatible with ARB, Nucleic Acids Res. 35 (2007) 7188–7196, https://doi.org/10.1093/nar/gkm864.
[28] Q. Wang, G.M. Garrity, J.M. Tiedje, J.R. Cole, Naïve Bayesian classifier for rapid assignment of rRNA sequences into the new bacterial taxonomy, Appl. Environ. Microbiol. 73 (2007) 5261–5267, https://doi.org/10.1128/AEM.00062-07.
[29] A. Hell, S. Labrie, L. Beaulieu, Effect of seaweed flakes addition on the development of bioactivities in functional Camembert-type cheese, Int. J. Food Sci. Technol. 53 (2018) 1054–1064, https://doi.org/10.1111/ijfs.13681.
[30] K. Krumov, G. Ivanov, A. Slavchev, N. Nenov, Improving the processed cheese quality by the addition of natural spice extracts, Adv. J. Food Sci. Technol. 2 (2010) 335–339.
[31] S. Zantar, F. Yedri, R. Mrabet, A. Laglaoui, M. Bakkali, M.H. Zerrouk, Effect of Thymus vulgaris and Origanum compactum essential oils on the shelf life of fresh goat cheese, J. Essent. Oil Res. 26 (2014) 76–84, https://doi.org/10.1080/10412905.2013.871673.
[32] J. Mei, Q. Guo, Y. Wu, Y. Li, H. Yu, Study of proteolysis , lipolysis , and volatile compounds of a camembert-type cheese manufactured using a freeze-dried Tibetan Kefir Co-culture during ripening, Food Sci. Biotechnol. 24 (2015) 393–402, https://doi.org/10.1007/s10068-015-0052-9.
[33] B. Shan, Y.Z. Cai, J.D. Brooks, H. Corke, Potential application of spice and herb extracts as natural preservatives in cheese, J. Med. Food 14 (2011) 284–290, https://doi.org/10.1089/jmf.2010.0009.
[34] C.C. Licón, M. Carmona, A. Molina, M.I. Berruga, Chemical, microbiological, textural, color, and sensory characteristics of pressed Ewe milk cheeses with saffron (Crocus sativus L.) during ripening, J. Dairy Sci. 95 (2012) 4263–4274, https://doi.org/10.3168/jds.2012-5389.
[35] Z. Tarakçı, F. Deveci, The effects of different spices on chemical, biochemical, textural and sensory properties of white cheeses during ripening, Mljekarstvo 69 (2019) 64–77, https://doi.org/10.15567/mljekarstvo.2019.0106.
[36] A. Hasanzadeh, Z. Raftani Amiri, M. Aminifar, Changes in the physicochemical, microstructural and rheological properties of traditional Kope cheese during ripening, Int. J. Dairy Technol. 71 (2018) 347–355, https://doi.org/10.1111/1471-0307.12434.
[37] H. Jaster, P. Judacewski, J.C.B. Ribeiro, A.A.F. Zielinski, I.M. Demiate, P.R. Los, A. Alberti, A. Nogueira, Quality assessment of the manufacture of new ripened soft cheese by Geotrichum candidum: physico-chemical and technological properties, Food Sci. Technol. 39 (2019) 50–58, https://doi.org/10.1590/fst.25717.
[38] S. Vyhmeister, C. Geldsetzer-Mendoza, M. Medel-Marabolí, A. Fellenberg, E. Vargas-Bello-Pérez, R.A. Ibáñez, Influence of using different proportions of cow and goat milk on the chemical, textural and sensory properties of Chanco–style cheese with equal composition, LWT–Food Sci. Technol. 112 (2019) 1–8, https://doi.org/10.1016/j.lwt.2019.05.124.
[39] J.J. Sheehan, A.D. Patel, M.A. Drake, P.L.H. Mcsweeney, Effect of partial or total substitution of bovine for caprine milk on the compositional, volatile, non-volatile and sensory characteristics of semi-hard cheeses, Int. Dairy J. 19 (2009) 498–509, https://doi.org/10.1016/j.idairyj.2009.03.009.
[40] A. Hassan, M.E. Johnson, J.A. Lucey, Changes in the proportions of soluble and insoluble calcium during the ripening of cheddar cheese, J. Dairy Sci. 87 (2004) 854–862, https://doi.org/10.3168/jds.S0022-0302(04)73229-4.
[41] Y. Zheng, Z. Liu, B. Mo, Texture profile analysis of sliced cheese in relation to chemical composition and storage temperature, J. Chem. 10 (2016) 1–10, https://doi.org/10.1155/2016/8690380.
[42] S.A. Mahgoub, M.F. Ramadan, K.M. El-Zahar, Cold pressed nigella sativa oil inhibits the growth of foodborne pathogens and improves the quality of domiati cheese, J. Food Saf. 33 (2013) 470–480, https://doi.org/10.1111/jfs.12078.
[43] G.H. Shin, W. Kim, Antibacterial and antiseptic activities of various spices to the mala food ingredients, Food Sci. Technol. 42 (2022) 1–6, https://doi.org/10.1590/fst.115821.
[44] M. Marino, N. Innocente, M. Maifreni, J. Mounier, J.F. Cobo-Díaz, E. Coton, L. Carraro, B. Cardazzo, Diversity within Italian cheesemaking brine-associated bacterial communities evidenced by massive parallel 16S rRNA gene tag sequencing, Front. Microbiol. 8 (2017) 1–13, https://doi.org/10.3389/fmicb.2017.02119.
[45] B.R. Yeluri Jonnala, P.L.H. McSweeney, J.J. Sheehan, P.D. Cotter, Sequencing of the cheese microbiome and its relevance to industry, Front. Microbiol. 9 (2018), https://doi.org/10.3389/fmicb.2018.01020.
[46] Á. Alegría, P. Szczesny, B. Mayo, J. Bardowski, M. Kowalczyk, Biodiversity in Oscypek, a traditional Polish Cheese, determined by culture-dependent and -independent approaches, Appl. Environ. Microbiol. 78 (2012) 1890–1898, https://doi.org/10.1128/AEM.06081-11.

[47] M.M. Fuka, S. Wallisch, M. Engel, G. Welzl, J. Havranek, M. Schloter, Dynamics of bacterial communities during the ripening process of different Croatian cheese types derived from raw Ewe's milk cheeses, PLoS One 8 (2013) 1–10, https://doi.org/10.1371/journal.pone.0080734.
[48] T. Allahghadri, I. Rasooli, P. Owlia, M.J. Nadooshan, T. Ghazanfari, M. Taghizadeh, S.D.A. Astaneh, Antimicrobial property, antioxidant capacity, and cytotoxicity of essential oil from cumin produced in Iran, J. Food Sci. 75 (2010), https://doi.org/10.1111/j.1750-3841.2009.01467.x.
[49] L.C. Yang, R. Li, J. Tan, Z.T. Jiang, Polyphenolics composition of the leaves of Zanthoxylum bungeanum maxim. grown in Hebei, China, and their radical scavenging activities, J. Agric. Food Chem. 61 (2013) 1772–1778, https://doi.org/10.1021/jf3042825.
[50] M. Lu, B. Yuan, M. Zeng, J. Chen, Antioxidant capacity and major phenolic compounds of spices commonly consumed in China, Food Res. Int. 44 (2011) 530–536, https://doi.org/10.1016/j.foodres.2010.10.055.
[51] D. Weragama, V. Weerasingha, L. Jayasumana, J. Adikari, J.K. Vidanarachchi, H. Priyashantha, The physicochemical, microbiological, and organoleptic properties and antioxidant activities of cream cheeses fortified with dried curry leaves (Murraya koenigii L.) powder, Food Sci. Nutr. 9 (2021) 5774–5784, https://doi.org/10.1002/fsn3.2551.
[52] M. Usha Rani, R. Meena, Comparative study on antioxidant potential and phytochemical composition of cumin and fennel, J. Herbs, Spices, Med. Plants 20 (2014) 245–255, https://doi.org/10.1080/10496475.2013.861379.
[53] S. Barak, D. Mudgil, Application of bioactives from herbs and spices for improving the functionality and shelf life of dairy products-A review, Biointerface Res. Appl. Chem. 13 (2023) 1–12, https://doi.org/10.33263/BRIAC132.141.
[54] M. Batool, M. Nadeem, M. Imran, I.T. Khan, J.A. Bhatti, M. Ayaz, Lipolysis and antioxidant properties of cow and buffalo cheddar cheese in accelerated ripening, Lipids Health Dis. (2018) 1–10.
[55] L. Hernández-Galán, A. Cardador-Martínez, D. Picque, H.E. Spinnler, M. López-del-Castillo Lozano, S.T. Martín del Campo, Angiotensin converting enzyme inhibitors and antioxidant peptides release during ripening of Mexican Cotija hard cheese Article, J. Food Res. 5 (2016) 85, https://doi.org/10.5539/jfr.v5n3p85.
[56] Y. Jie, S. Li, C.T. Ho, Chemical composition, sensory properties and application of Sichuan pepper (Zanthoxylum genus), Food Sci. Hum. Wellness 8 (2019) 115–125, https://doi.org/10.1016/j.fshw.2019.03.008.
[57] K. Srinivasan, Cumin (Cuminum cyminum) and black cumin (Nigella sativa) seeds: traditional uses, chemical constituents, and nutraceutical effects, Food Qual. Saf. 2 (2018) 1–16, https://doi.org/10.1093/fqsafe/fyx031.
[58] E. Seifu, Chemical composition and microbiological quality of Metata Ayib: a traditional Ethiopian fermented cottage cheese, Int. Food Res. J. 20 (2013) 93–97.