RESEARCH ARTICLE Asian Journal of Dairy and Food Research, Volume 43 Issue 3: 396-403 (September 2024)

Effect of Spice Powder on Physicochemical Characteristics, Functional Properties and Microbiological Quality in Soft Cheese

N.D. Arkan[1], T. Setyawardani[1], J. Sumarmono[1], R. Naufalin[2], S.S. Santosa[1], A.H.D. Rahardjo[1]

10.18805/ajdfr.DRF-374

ABSTRACT

Background: The development of soft cheese as a functional food product includes the use of spices rich in antioxidants, such as cinnamon (*Cinnamomum burmannii*), lemongrass (*Cymbopogon citratus*) and turmeric (*Curcuma longa* L.). This study was focused to investigate the effect of the addition of cinnamon, lemongrass and turmeric powder either singly or in combination, on the physicochemical characteristics, functional properties and microbiological quality of soft cheese.

Methods: Soft cheese samples were added with cinnamon, lemongrass and turmeric powder with a maximum percentage of 3%, which consists of eight treatments either singly or in combination, then analyzed for pH, total titratable acids (TTA), total solids, color, texture profile, antioxidant activity, total phenolic content (TPC), fatty acid using the gas chromatography (GC) method, total bacteria and total yeast/molds.

Result: The pH of soft cheese ranges from 5.33±0.45 to 5.90±0.06, TTA 1.29±0.59 to 1.90±0.07%, total solids 42.68±8.06 to 60.21±1.61%, brightness color (L*) 64.10±2.7 to 84.50±2.88, redness (a*) 3.60±0.20 to 9.60±0.43, yellowness (b*) 8.90±5.75 to 20.20±4.78 and total bacteria 4.881±0.02 to 6.835±0.01 log cfu/g. The texture profile (hardness, springiness, cohesiveness, adhesiveness, gumminess and chewiness) increased significantly. Total fatty acids range from 30.24 to 44.82, with 45% unsaturated fatty acids (UFAs) and 55% saturated fatty acids (SFAs). The combination of cinnamon and turmeric powder produced the highest antioxidant activity of 79.11%. The combination of lemongrass and turmeric powder produced the highest palmitic acid (C16:0) of 23.69, TPC of 50.91 mg GAE/g and total yeast/molds of 4.795 ±0.03 log cfu/g.

Key words: Functional properties, Microbiological, Soft cheese, Spices, Texture profile.

INTRODUCTION

Cheese is a fermented milk product produced worldwide with a wide range of characteristics. Cheese contains various proteins, minerals, and vitamins, all of which contribute to its nutritional value (Gholamhosseinpour *et al.*, 2023). Cheese is made by forming curds that are coagulated using rennets (Fox and McSweeney, 2017). Today, consumers need healthy foods, known as functional foods. Functional foods are popular in both social and scientific media. According to Granato *et al.* (2020), antioxidants are the most widely used functional ingredient. The development of cheese as a functional food product includes the use of spices rich in antioxidants, such as cinnamon (*Cinnamomum burmannii*), lemongrass (*Cymbopogon citratus*) and turmeric (*Curcuma longa* L.). These species have the advantage of being a source of phenolics and flavonoids. In previous studies, spices exhibited antimicrobial and antioxidant properties because of their main chemical compounds (Jessica Elizabeth *et al.*, 2017).

Dairy products play an essential role in the human diet around the world. The trade of 'Processed Cheese' from India has increased significantly over the last two decades (Prajapati *et al.*, 2022). An Indian variety of soft cheese is Paneer a versatile nutrient-dense food used as a pedestal substance in various culinary preparations and contains a large amount of high-quality protein, fat and minerals (Prajapati *et al.*, 2023). Danke, a type of fresh soft cheese made of bovine and buffalo milk is a traditional dairy product used in South Sulawesi, Indonesia (Al-Baarri *et al.*, 2018). In Algeria, cow's milk is transformed into soft type camembert cheese either traditionally or industrially (Dahou *et al.*, 2020). Soft cheese is a dairy product with a semi-solid and viscous consistency. The properties of soft cheese are high water

[1]Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, Indonesia.
[2]Department of Food Technology, Agricultural Faculty, Jenderal Soedirman University, Purwokerto, Indonesia.

Corresponding Author: T. Setyawardani, Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, Indonesia. Email: triana.setyawardani@unsoed.ac.id

How to cite this article: Arkan, N.D., Setyawardani, T., Sumarmono, J., Naufalin, R., Santosa S.S. and Rahardio, A.H.D. (2024). Effect of Spice Powder on Physicochemical Characteristics, Functional Properties and Microbiological Quality in Soft Cheese. Asian Journal of Dairy and Food Research. 43(3): 396-403. doi: 10.18805/ajdfr.DRF-374.

Submitted: 21-11-2023 **Accepted:** 27-02-2024 **Online:** 22-05-2024

activity and low acidity Gould *et al*. (2014). According to Choi *et al*. (2016), many cheese-borne outbreaks have been linked to soft cheese (≥ 50% moisture content), with most of these outbreaks caused by postpasteurization contamination.

Spices added to cheese may alter its physicochemical characteristics, functional properties, and microbiological quality. Cinnamon, lemongrass, and turmeric are added to cheese either singly or in combination to impart various characteristics, including color, texture, aroma and flavor. These spices are relatively inexpensive and abundant and are often used as medicine or food in traditional societies. Spice has long been used for both culinary and medicinal purposes. Traditionally, spices as part of the diet, have holistic effects on human health. However, cheese with added spice powder has not been found in the market and it is currently not widely produced making this study an element of novelty. Previous studies have investigated white soft cheese with the addition of cinnamon powder (Hamid and Abdelrahman, 2012), Surk cheese with spice content (Güler, 2014) and Kariesh cheese with the addition of turmeric extract (Hasneen *et al.*, 2020).

Soft cheese can be enhanced using herbs and spices. Spices have been used as preservatives, flavorings and therapeutic agents to enhance food quality (El-Sayed and Youssef, 2019). The spices used in this study were in powder form, which influences cheese characteristics. These characteristics are influenced by the percentage and type of spice powder added. This study aimed to investigate the effects of the addition of cinnamon, lemongrass and turmeric powder either singly or in combination with milk-based cheese and its effect on physicochemical characteristics (pH, total titratable acids, total solids, color and texture profile), functional properties (total phenolic content, antioxidant activity and fatty acids) and microbiological quality (total bacteria and total yeast/molds).

MATERIALS AND METHODS

The research was carried out at the Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, Indonesia. Fatty acid analysis was carried out at the IPB University, Bogor, Indonesia. The research period was carried out from March to August 2023. The material used was cow milk from the Unsoed Experimental Farm, cinnamon, lemongrass, and turmeric powder. The treatments were shown in Table 1.

Soft cheese manufacture

The manufacture of soft cheese starts with pasteurization of 85°C whole cow's milk for 15 seconds, then allowed to cool down to 40°C in eight batches, with each batch containing 1 liter of milk. The subsequent step was adding 0.2 g $CaCl_2$ 0.2 and 0.01 g starter mesophilic then incubated 37°C to pH 6.1. The function of $CaCl_2$ is to shorten coagulation time and increase curd strength. 0.3 mL pure calf rennet was added and kept at 37°C in an incubator for 1 hour (coagulation process). The curd was cut into 2×2 cm. The next step was to separate the curd and whey, and the curd that was formed was added to the spice powder according to the treatment and then hung overnight using a cheesecloth to separate the whey. The separated curd and whey were then pressed using a cheese mold for 1 hour. Finally, the soft cheese was covered with 2% table salt and stored in a refrigerator for 24 hours before measurement. The process of soft cheese manufacture can be observed in the Flow Diagram 1.

Measurement of physicochemical characteristics

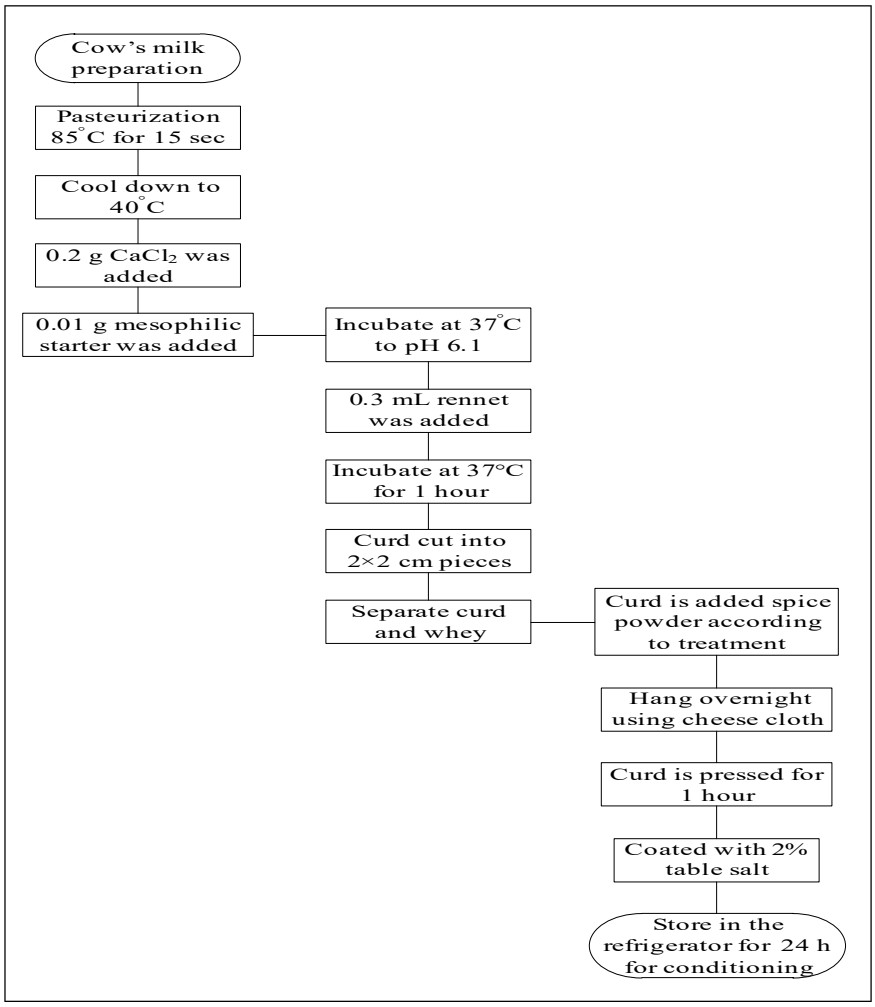
The pH was measured using a pH meter and Total Titratable Acidity (TTA) was measured by titration with 0.1 N NaOH (Sadler and Murphy, 2010). The measurement of total solids according to the methods by AOAC (2016). The color measurements were performed using a colorimeter. The texture profile was measured according to the methods by Chavan and Goyal (2018) using a texture profile analyzer (TAXT plus, Stable Microsystem, Godalming, UK). Cheese samples cut into cubes were uniformly pressed with the probe 2 times. The probe speed used was 2 mm/s with the sample pressed to 30% of its initial height. The test results were observed in the TA-XT 21 texture analyzer software and then recorded.

Measurement of functional properties

The total phenolic content (TPC) was measured according to the methods by Sahu and Saxena (2013) using the Folin-Ciocalteu reagent and UV-Vis spectrophotometry at 760 nm. The antioxidant activity was measured according to the methods by Vukić *et al.* (2022) with spectrophotometric analysis of DPPH (2,2-diphenyl-picrylhydrazyl) using a spectrophotometer at 517 nm. The fatty acid analysis was measured according to the methods by Golay *et al.* (2016) using gas chromatography.

Table 1: Treatment details.

Treatment	Addition of spice powder
T0	Soft cheese without added spice powder
T1	Soft cheese + 3% cinnamon powder
T2	Soft cheese + 3% lemongrass powder
T3	Soft cheese + 3% turmeric powder
T4	Soft cheese + 1.5% cinnamon powder + 1.5% lemongrass powder
T5	Soft cheese + 1.5% cinnamon powder + 1.5% turmeric powder
T6	Soft cheese + 1.5% lemongrass powder + 1.5% turmeric powder
T7	Soft cheese + 1% cinnamon powder + 1% lemongrass powder + 1% turmeric powder



Flow diagram 1: The process of soft chesse manufacture.

Measurement of microbiological quality

Total bacteria was measured according to the methods by Maturin and Peeler (2001), the number of colonies growing on each plate was calculated using the standard plate count formula with the criterion of 25–250 colonies, while the total yeast/molds number of colonies growing on each plate was calculated based on the BAM (2001) criteria of 10-150 colonies (Tournas *et al*., 2001).

RESULTS AND DISCUSSION

Physicochemical characteristics

Table 2 shows significant differences ($P<0.05$) in the total solids, brightness, redness, and yellowness of soft cheese. This study resulted in total solids ranging from 42.68 to 60.21%. In accordance with Standards National Indonesian (SNI), the minimum required total solid content of cheese is 25% (BSN, 2018). According to Cipolat-Gotet *et al*. (2013), the solid content in fresh curd after brining was 48%. In previous study, Valdeón cheese contained between 51.93-62.74 g of total solids per 100 g. The addition of spice powder increases the total solid content of cheese, which occurs due to increased yield (Diezhandino *et al*., 2015). The decrease in soft cheese brightness was caused by cinnamon, which has a natural blackish-brown color. Cinnamon is pale yellowish-brown in color (Suriyagoda *et al*., 2021). The yellowness increase was caused by curcumin, a yellow compound in turmeric (Rijai, 2019).

Table 3 demonstrates that the inclusion of spice powder significantly increased the hardness, springiness, cohesiveness, adhesiveness, gumminess and chewiness of soft cheese. The addition of 3% lemongrass powder (T2) resulted in the highest springiness and cohesiveness, while the addition of 3% cinnamon powder (T1) resulted in the highest hardness, gumminess, and chewiness. The interaction between the spice powder and casein was likely responsible for this effect, which also resulted in the highest total solids content. The increased total solids content of soft cheese contributes to an enhanced texture profile. According to Kim *et al.* (2014), the addition of cinnamon powder leads to an increase in both hardness and chewiness of food. The hardness of food increases when the surface

Table 2: pH value, total titratable acids, total solids and soft cheese color with the addition of spice powder.

Cheese	pH	TTA (%)	Total solids (%)	Color		
				L*	a*	b*
T0	5.33±0.45	1.76±0.16	42.68±8.06^{a}	84.50±2.88^{d}	6.18±2.13^{abc}	8.90±5.75^{a}
T1	5.50±0.42	1.29±0.50	60.21±1.61^{d}	64.10±2.74^{a}	7.24±1.18^{cd}	10.46±1.81^{ab}
T2	5.34±0.19	1.90±0.07	53.45±3.29^{cd}	72.70±2.72^{bc}	3.60±0.20^{a}	11.93±4.69^{abc}
T3	5.65±0.14	1.55±0.10	51.13±6.96^{bc}	73.03±2.70^{bc}	9.60±0.43^{d}	20.20±4.78^{d}
T4	5.43±0.19	1.29±0.59	59.22±0.67^{cd}	66.10±1.38^{a}	3.99±2.65^{ab}	10.20±3.27^{ab}
T5	5.90±0.06	1.49±0.45	59.12±3.20^{cd}	66.13±1.04^{a}	6.12±1.71^{abc}	18.56±2.08^{cd}
T6	5.43±0.33	1.71±0.27	44.90±2.43^{ab}	74.76±4.24^{c}	4.70±0.60^{abc}	17.26±4.95^{bcd}
T7	5.76±0.23	1.80±0.29	56.11±2.45^{cd}	68.26±2.39^{ab}	6.65±1.05^{bc}	16.36±1.45^{bcd}
Sig.	ns	ns	*	*	*	*

Data are presented as mean±standard deviation. Data with different superscripts within the same column are significantly different. ns= non-significant, * = Significant (P<0.05).

Table 3: Texture profile of soft cheese with the addition of spice powder.

Cheese	Hardness (N)	Springiness (mm)	Cohesiveness	Adhesiveness (J)	Gumminess (N)	Chewiness (J)
T0	172.49±24.44^{a}	0.13±0.02^{a}	0.15±0.03^{a}	-8.30±7.73	167.14±15.01^{a}	25.94±3.14^{a}
T1	337.17±44.42^{b}	0.22±0.01^{a}	0.16±0.01^{a}	-5.53±0.70	334.43±4.70^{c}	84.90±1.41^{f}
T2	222.30±12.66^{a}	0.66±0.02^{b}	0.43±0.22^{b}	-3.24±1.50	229.31±22.31^{ab}	74.48±0.77^{e}
T3	202.32±36.49^{a}	0.60±0.07^{b}	0.38±0.12^{b}	-4.72±0.96	265.10±3.93^{bc}	58.48±0.99^{d}
T4	199.12±25.07^{a}	0.21±0.05^{a}	0.15±0.01^{a}	-4.13±1.70	259.30±63.93^{bc}	47.53±3.43^{c}
T5	261.50±77.53^{ab}	0.22±0.02^{a}	0.16±0.03^{a}	-5.65±1.24	228.56±88.51^{ab}	74.02±2.93^{e}
T6	200.78±65.07^{a}	0.65±0.09^{b}	0.32±0.10^{ab}	-6.57±0.34	279.76±16.18^{bc}	41.39±5.51^{bc}
T7	213.40±74.36^{a}	0.21±0.03^{a}	0.18±0.01^{a}	-2.28±0.76	281.73±13.09^{bc}	34.70±8.16^{b}

Data are presented as mean±standard deviation. Data with different superscripts within the same column are significantly different (P<0.05).

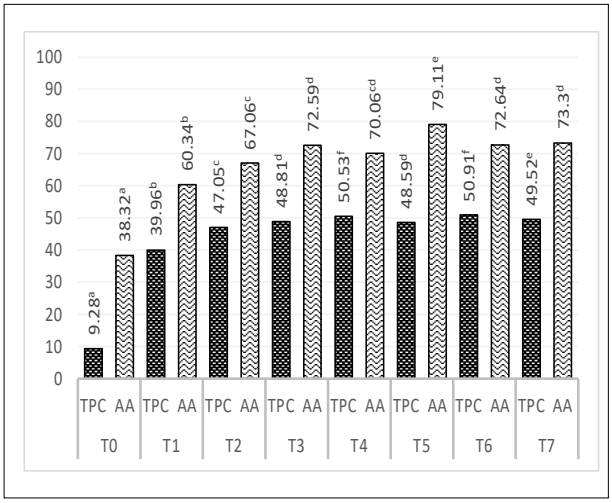


Fig 1: Average total phenolic content (TPC) (mg GAE/g) and antioxidant activity (AA) (%) of soft cheese with the addition of spice powder.

water level decreases, while the chewiness is likely to increase due to the interaction between dietary fiber and water. Wen *et al*. (2021) state that the moisture content of food affects its chewiness, hardness, and springiness.

Functional properties

Fig 1 displays the results of this study that examined the effects of adding spice powder to soft cheese on functional properties. This study found that the total phenolic content (TPC) ranged from 9.28-50.91 mg GAE/g and Antioxidant Activity (AA) ranged from 38.32-79.11%, both of which increased due to the phenolic compounds present in the spice powder. These compounds are known to improve the functional properties of cheeses, as suggested by Lee *et al*. (2016). Similarly, Lucera *et al*. (2018) found that the TPC, flavonoids and antioxidant activity of spreadable cheese containing grape pomace increased. Another study showed that the addition of vegetable flours to Primosale cheese increased its TPC, which ranged from 1.22-10.59 mg GAEs/gdw (Costa *et al*., 2018).

Table 4 displays the range of total fatty acid content present in soft cheese which is between 30.24 to 44.82. Unsaturated fatty acids (UFAs) were produced in an amount of 45%, whereas saturated fatty acids (SFAs) were produced in an amount of 55%. The highest type of UFAs obtained was oleic acid (C18:1n9), which ranged from 5.93 to 10.47, while the highest type of SFAs obtained was palmitic acid (C16:0), ranging from 13.45 to 23.69. The addition of 3% cinnamon powder to the soft cheese increased the oleic acid content. According to Xue *et al*. (2023), oleic acid is a natural component of cinnamon. This acid has several benefits including reducing inflammation, inhibiting cancer proliferation and lowering blood pressure (Sales-Campos *et al*., 2013). The combination of lemongrass and turmeric powder (T6) increased the palmitic acid content. In previous

Table 4: Fatty acids of soft cheese with the addition of spice powder.

Component	Treatment							
	T0	T1	T2	T3	T4	T5	T6	T7
Fat content	25.89	9.49	4.00	5.29	4.90	7.09	4.80	3.48
Fatty acid**								
Butryc acid, C4:0	0.18	0.15	0.16	0.16	0.19	0.46	0.64	1.24
Caproic acid, C6:0	0.14	0.13	0.07	0.08	0.11	0.19	0.17	0.14
Caprilic acid, C8:0	0.23	0.22	0.16	0.16	0.26	0.42	0.42	0.31
Capric acid, C10:0	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Undecanoic acid, C11:0	0.45	0.39	0.31	0.32	0.38	0.60	0.58	0.42
Myristic acid, C14:0	4.10	3.67	3.22	3.20	3.81	5.68	5.80	3.82
Myristoleic acid, C14:1	0.20	0.20	0.14	0.15	0.15	0.20	0.18	0.17
Pentadecanoic acid, C15:0	0.14	0.12	0.11	0.11	0.12	0.16	0.16	0.13
Palmitic acid, C16:0	17.24	16.07	15.79	13.45	15.84	23.22	23.69	15.26
Palmitoleic acid, C16:1	0.37	0.52	0.38	0.54	0.30	0.44	0.43	0.32
Heptadecanoic acid, C17:0	0.08	0.10	0.09	0.10	0.07	0.00	0.00	0.08
Cis-10-Heptadecanoic acid, C17:1	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Stearic acid, C18:0	3.64	3.65	3.83	3.01	3.38	4.44	4.68	2.96
Elaidic acid, C18:1n9t	0.00	0.03	0.09	0.12	0.12	0.07	0.07	0.12
Oleic acid, C18:1n9c	8.77	10.47	7.57	8.74	6.32	8.68	7.91	5.93
Linoieiaidic acid, C18:2n9t	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Linoleic acid, C18:2n6c	0.08	0.09	0.07	0.10	0.08	0.11	0.10	0.08
Arachidic acid, C20:0	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Cis-11-Eicosenoic acid, C20:1	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Linoleic acid, C18:3n3	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total fatty acid	35.62	35.93	31.98	30.24	31.14	44.66	44.82	30.97

** = Concentration in fat.

Table 5: Total bacteria and yeast/molds of soft cheese with the addition of spice powder.

Cheese	Total bacteria (log cfu/g)	Total yeast/molds (log cfu/g)
T0	4.881±0.02^{a}	5.984±0.02^{c}
T1	5.871±0.02^{b}	6.059±0.04^{d}
T2	6.835±0.01^{f}	5.847±0.01^{b}
T3	6.220±0.04^{e}	6.059±0.04^{d}
T4	3.768±0.01^{d}	1.727±0.01^{a}
T5	4.609±0.03^{f}	4.279±0.02^{e}
T6	2.702±0.02^{bc}	2.675±0.01^{b}
T7	4.795±0.03^{g}	2.746±0.04^{c}

Data are presented as mean±standard deviation. Data with different superscripts within the same column are significantly different ($P<0.05$).

study, palmitic acid and oleic acid were found in lemongrass (Duru and Enyoh, 2020) and turmeric (Zaman and Akhtar, 2013). Palmitic acid can induce lipotoxicity and oxidative stress stress (Sun *et al.*, 2016) and increase LDL serum cholesterol levels (Daneshyar *et al.*, 2011). Fig 2 shows the fatty acid chromatogram of soft cheese with the addition of spice powder.

Microbiological quality

Table 5 displays the microbiological quality of soft cheese, which is measured by examining the total bacteria and yeast/molds present. The average total bacteria count ranged from 4.881 to 6.835 log cfu/g, while the total yeast/molds ranged from 1.727 to 4.795 log cfu/g. In another study, the average total bacterial count in fresh white cheese was $\log_{10}$ 7.7 cfu/g (Haddad and Yamani, 2017). The combination of cinnamon and lemongrass powder (T4) had the highest total bacteria count, while the combination of lemongrass and turmeric powder (T6) had the highest total yeast/molds count. When spice powder is added to soft cheese that has a high water content, it can stimulate the microbial population due to increased water activity. Although spice powder has a lower water content, it contains a high amount of bacteria, which can possibly enhance the total bacterial count of soft cheese. A study by Lee *et al*. (2018) found that commercial spices

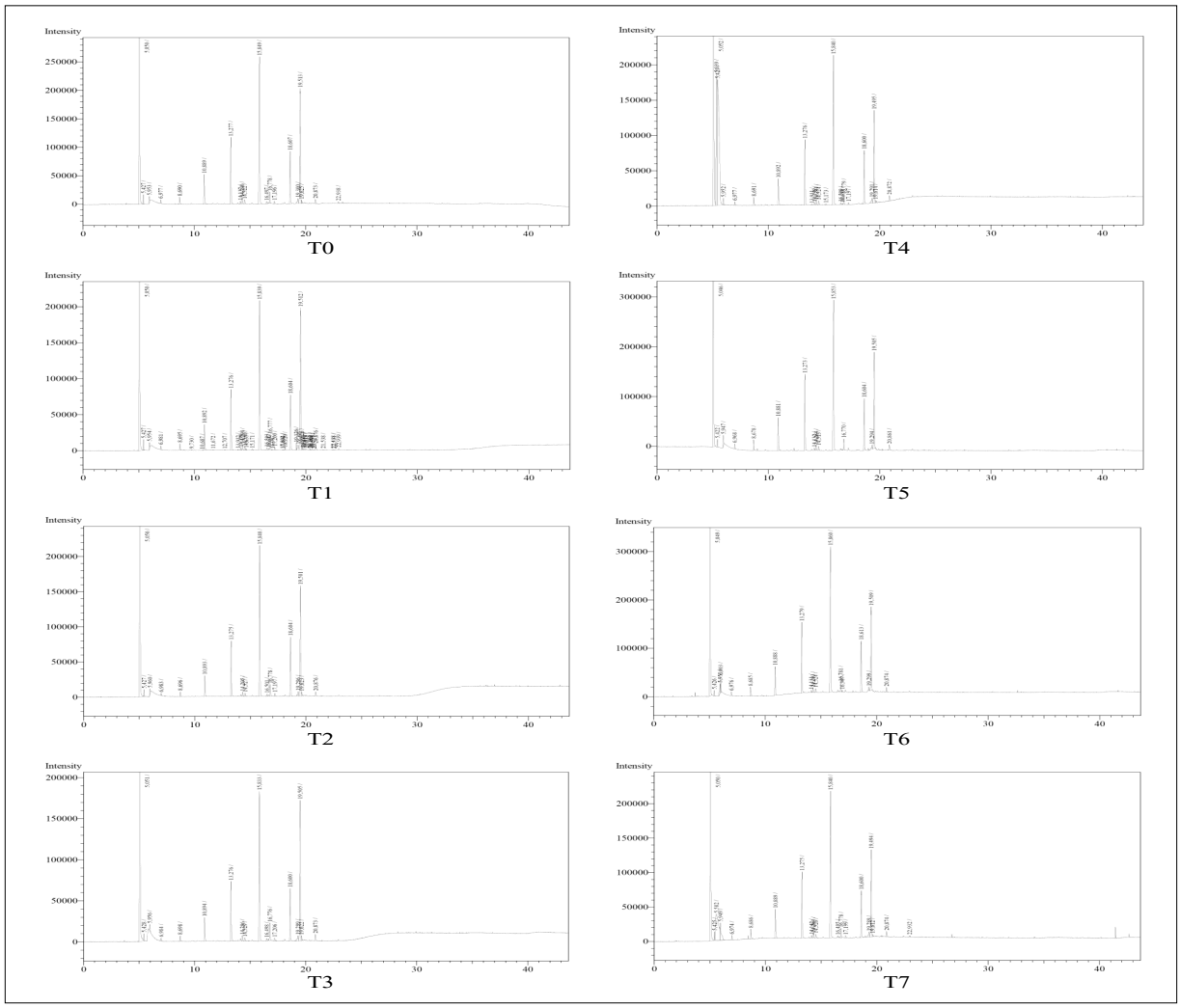


Fig 2: Fatty acid chromatogram of soft cheese with the addition of spice powder.

contained a total of 13.9% *Bacillus cereus*. It's possible for the total yeast/molds count to increase when soft cheese is stored in a refrigerator during the conditioning process. In another study by Hadjilouka *et al.* (2015), yeasts and molds were found to grow at 10 and 15°C when lemongrass essential oil was applied to packaged rocket salads, but the population did not exceed 5.5 log cfu/g^{-1}. El-Sayed and Youssef (2019) found that the storage duration affects the total bacterial count, mold and yeast in soft cheese.

CONCLUSION

Spice powder added to soft cheese increases its total solids content, redness, yellowness, texture profile, bacteria and yeast/molds. The combination of lemongrass and turmeric powder resulted in the highest TPC value. The cheese's antioxidant activity was increased by a combination of cinnamon and turmeric powder. The best treatment was the lemongrass and turmeric powder combination, which improved the cheese's functional properties.

ACKNOWLEDGEMENT

This research received financial support from Indonesia through RISIN Research Grant 2023.

Conflict of interest

All authors declare that they have no conflicts of interest.

REFERENCES

Al-Baarri, A.N., Legowo, A.M., Arum, S.K., Hayakawa, S. (2018). Extending shelf life of Indonesian soft milk cheese (Dangke) by lactoperoxidase system and lysozyme. International Journal of Food Science. 1-7. doi: 10.1155/2018/4305395.

AOAC, (2016). Official Methods of Analysis, 20th edn. (online). AOAC International, Rockville, MD.

BSN. (2018). Keju olahan. SNI 2980:2018. Badan Standardisasi Nasional, Jakarta.

Chavan, R.S. and Goyal, M.R. (2018). Technological Interventions in Dairy Science: Innovative Approaches in Processing, Preservation and Analysis of Milk Products. CRC Press.

Choi, K.H., Lee, H., Lee, S., Kim, S., Yoon, Y. (2016). Cheese microbial risk assessments- A review. Asian-Australasian Journal of Animal Sciences. 29(3): 307-314. doi: 10.5713/ajas.15.0332.

Cipolat-Gotet, C., Cecchinato, A., De Marchi, M., Bittante, G. (2013). Factors affecting variation of different measures of cheese yield and milk nutrient recovery from an individual model cheese-manufacturing process. Journal of Dairy Science. 96(12): 7952-7965. doi: 10.3168/jds.2012-6516.

Costa, C., Lucera, A, Marinelli, V., Del Nobile, M.A., Conte, A. (2018). Influence of different by-products addition on sensory and physicochemical aspects of Primosale cheese. Journal of Food Science and Technology. 55: 4174-4183. doi: 10.1007/s13197-018-3347-z.

Dahou, A.A., Bekada, A.M.A., Medjahed, M., Tahlaiti, H., Rechidi, S.N., Homrani, A. (2020). Characterization of natural lactic flora in a soft cheese "Camembert of the tessala" made from thermised milk of local breed cow "Brown of the atlas". Asian Journal of Dairy and Food Research. 39(1): 30-34. doi: 10.18805/ajdfr.DR-158.

Daneshyar, M., Ghandkanlo, M.A., Bayeghra, F.S., Farhangpajhoh, F., Aghaei, M. (2011). Effects of dietary turmeric supplementation on plasma lipoproteins, meat quality and fatty acid composition in broilers. South African Journal of Animal Science. 41(4): 420-428. doi: 10.4314/sajas.v41i4.13.

Diezhandino, I., Fernández, D., González, L., McSweeney, P., Fresno, J. (2015). Microbiological, physico-chemical and proteolytic changes in a Spanish blue cheese during ripening (Valdeón cheese). Food Chemistry. 168: 134-141. doi: 10.1016/j.foodchem.2014.07.039.

Duru, I.A. and Enyoh, C.E. (2020). Comparative analysis of phytochemicals and fatty acids from lemon peel and lemongrass essential oils by GC-FID technique. Journal of Medicinal Plants. 8(5): 178-182.

El-Sayed, S.M. and Youssef, A.M. (2019). Potential application of herbs and spices and their effects in functional dairy products. Heliyon. 5(6): 1-7. doi: 10.1016/j.heliyon.2019.e01989.

Fox, P.F. and McSweeney, P.L. (2017). Chapter 1 - Cheese: an overview. Cheese (Fourth edition). 5-21. doi: 10.1016/B978-0-12-417012-4.00001-6.

Gholamhosseinpour, A., Karimi Davijani, A., Karami, M. (2023). Investigating the effect of ozone on the physicochemical, microbial and sensory properties of brined ultrafiltered cheese during ripening. Iranian Food Science and Technology Research Journal. 1-28. doi: 10.22067/ifstrj.2023.81 663. 1244.

Golay, P.A. and Moulin, J. (2016). Determination of labeled fatty acids content in milk products, infant formula and adult/pediatric nutritional formula by capillary gas chromatography: Collaborative study, final action 2012.13. Journal of AOAC International. 99(1): 210-222. doi: 10.5740/jaoacint.15-0140.

Gould, L.H., Mungai, E., Behravesh, C.B. (2014). Outbreaks attributed to cheese: Differences between outbreaks caused by unpasteurized and pasteurized dairy products, United States, 1998–2011. Foodborne Pathogens and Disease. 11(7): 545-551. doi: 10.1089/fpd.2013.1650.

Granato, D., Barba, F.J., Bursać Kovaèević, D., Lorenzo, J.M., Cruz, A.G., Putnik, P. (2020). Functional foods: Product development, technological trends, efficacy testing, and safety. Annual Review of Food Science and Technology. 11: 93-118.

Güler, Z. (2014). Profiles of organic acid and volatile compounds in acid-type cheeses containing herbs and spices (Surk cheese). International Journal of Food Properties. 17(6): 1379-1392. doi: 10.1080/10942912.2012.697957.

Haddad, M. and Yamani, M. (2017). Microbiological quality of soft white cheese produced traditionally in Jordan. Journal of Food Processing and Technology. 8(12): 706-712. doi: 10.4172/2157-7110.1000706.

Hadjilouka, A., Polychronopoulou, M., Paramithiotis, S., Tzamalis, P., Drosinos, E.H. (2015). Effect of lemongrass essential oil vapors on microbial dynamics and Listeria monocytogenes survival on rocket and melon stored under different packaging conditions and temperatures. Microorganisms. 3(3): 535-550. doi: 10.3390/microorganisms3030535.

Hamid, O.I.A. and Abdelrahman, N.A.M. (2012). Effect of adding cardamom, cinnamon and fenugreek to goat's milk curd on the quality of white cheese during storage. International Journal of Dairy Science. 7(2): 43-50. doi: 10.3923/ijds.2012.43.50.

Hasneen, D.F., Zaki, N.L., Abbas, M.S., Soliman, A.S., Ashoush, I.S., Fayed, A.E. (2020). Comparative evaluation of some herbs and their suitability for skimmed milk yoghurt and cast Kariesh cheese fortification as functional foods. Annals of Agricultural Sciences. 65(1): 6-12. doi: 10.1016/j.aoas.2020.05.001.

Jessica Elizabeth, D.L.T., Gassara, F., Kouassi, A.P., Brar, S.K., Belkacemi, K. (2017). Spice use in food: Properties and benefits. Critical Reviews in Food Science and Nutrition. 57(6): 1078-1088. doi: 10.1080/10408398.2013.858235.

Kim, D.H., Lim, Y.T., Park, Y.J., Yeon, S.J., Jang, K.I. (2014). Antioxidant activities and physicochemical properties of tteokbokki rice cakes containing cinnamon powder. Food Science and Biotechnology. 23(2): 425-430. doi: 10.1007/s10068-014-0058-8.

Lee, N.K., Jeewanthi, R., Park, E.H., Paik, H.D. (2016). Physicochemical and antioxidant properties of Cheddar-type cheese fortified with *Inula britannica* extract. Journal of Dairy Science. 99(1): 83-88. doi: 10.3168/jds.2015-9935.

Lee, S.H., Mun, K.H., Kim, N.Y.S., Kim, J.B. (2018). Evaluation of microbiological safety of commercial spices. Korean Journal of Food Preservation. 25(6): 706-714. doi: 10.1 1002/kjfp.201 8.25.6.706.

Lucera, A., Costa, C., Marinelli, V., Saccotelli, M.A., Del Nobile, M.A., Conte, A. (2018). Fruit and vegetable by-products to fortify spreadable cheese. Antioxidants. 7(5): 1-10. doi: 10.3390/antiox7050061.

Maturin, L. and Peeler, J. (2001). BAM: Aerobic plate count. US Food and Drug Administration: Silver Spring, MD, USA.

Prajapati, D.M., Kumar, V., Dave, K.D., Jagalan, V. (2022). The Trade Competitiveness of Indian Processed Cheese. Bhartiya Krishi Anusandhan Patrika. 37(2): 144-150. doi: 10.18805/BKAP480.

Prajapati, P., Garg, M., Singh, N., Chopra, R., Mittal, A. (2023). Extension of shelf life of Paneer-an Indian variety of soft cheese: A review. Asian Journal of Dairy and Food Research. doi: 10.18805/ajdfr.DR-1990.

Rijai, L. (2019). Review of phytochemicals and its biological activities and contemporary nutraceuticals. Journal of Tropical Pharmacy and Chemistry. 4(6): 298-310. doi: 10.25026/jtpc.v4i6.216.

Sadler, G.D. and Murphy, P.A. (2010). pH and titratable acidity. Food Analysis. 4: 219-238. doi: 10.1007/978-1-4419-1478-1.

Sahu, R. and Saxena, J. (2013). Screening of total phenolic and flavonoid content in conventional and non-conventional species of curcuma. Journal of Pharmacognosy and Phytochemistry. 2(1): 176-179.

Sales-Campos, H., Reis de Souza, P., Crema Peghini, B., Santana da Silva, J., Ribeiro Cardoso, C. (2013). An overview of the modulatory effects of oleic acid in health and disease. Mini Reviews in Medicinal Chemistry. 13(2): 201-210. doi: 10.2174/138955713804805193.

Sun, P., Wang, T., Chen, L., Yu, B.W., Jia, Q., Chen, K.X., Fan, H.M., Li, Y.M., Wang, H.Y. (2016). Trimer procyanidin oligomers contribute to the protective effects of cinnamon extracts on pancreatic β-cells *in vitro*. Acta Pharmacologica Sinica. 37(8): 1083-1090. doi: 10.1038/aps.2016.29.

Suriyagoda, L., Mohotti, A.J., Vidanarachchi, J.K., Kodithuwakku, S.P., Chathurika, M., Bandaranayake, P.C., Hetherington, A.M., Beneragama, C.K. (2021). "Ceylon cinnamon": much more than just a spice. Plants, People, Planet. 3(4): 319-336. doi: 10.1002/ppp3.10192.

Tournas, V., Stack, M.E., Mislivec, P.B., Koch, H.A., Bandler, R. (2001). BAM Chapter 18: Yeasts, Molds and Mycotoxins. Bacteriological Analytical Manual. Food and Drug Administration, Washington, DC.

Vukić, D., Pavlić, B., Vukić, V., Ilièić, M., Kanurić, K., Bjekić, M., Zeković, Z. (2022). Antioxidative capacity of fresh kombucha cheese fortified with sage herbal dust and its preparations. Journal of Food Science and Technology. 59(6): 2274-2283. doi: 10.1007/s13197-021-05241-y.

Wen, P., Zhu, Y., Luo, J., Wang, P., Liu, B., Du, Y., Jiao, Y., Hu, Y., Chen, C., F. Ren, F. (2021). Effect of anthocyanin-absorbed whey protein microgels on physicochemical and textural properties of reduced-fat Cheddar cheese. Journal of Dairy Science. 104(1): 228-242. doi: 10.3168/jds.2020-18450.

Xue, T., Xue, Y., Fang, Y., Lu, C., Fu, Y., Lai, Z., Qin, X., Huang, F., Zeng, Z., Huang, J. (2023). Exploring myocardial ischemia-reperfusion injury mechanism of cinnamon by network pharmacology, molecular docking, and experiment validation. Computational and Mathematical Methods in Medicine. 1-14. doi: 10.1155/2023/1066057.

Zaman, S. and Akhtar, N. (2013). Effect of turmeric (*Curcuma longa* Zingiberaceae) extract cream on human skin sebum secretion. Tropical Journal of Pharmaceutical Research. 12(5): 665-669. doi: 10.4314/tjpr.v12i5.1.