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Manufacture of Smoked Goat's Yoghurt Fortified with Whole Triticale Flour

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ABSTRACT

The objective of this study was to evaluate the effect of adding different levels of liquid smoke (LS) (0.02% and 0.03%) and triticale flour (TF) (1.0% and 2.0%) to goat's milk on the physicochemical, rheological, and sensory properties of yogurt. The results showed a direct relationship between the amount of triticale flour added and the curd tension and syneresis values of the yogurt. The addition of liquid smoke (LS) reduced titratable acidity, total volatile fatty acids, viscosity, water-holding capacity, and the counts of total viable bacteria and lactic acid bacteria. In contrast, it increased pH, total phenolic compounds, and antioxidant activity. On the other hand, the addition of TF to goat's milk significantly increased acidity, total solids, total protein, fat content, total volatile fatty acids, viscosity, water-holding capacity, counts of total viable bacteria and lactic acid bacteria, dietary fiber, phenolic content, total antioxidant activity, and carbohydrate concentrations compared to the control. Yogurt treatments containing LS or TF were preferred during the storage period based on sensory evaluation scores. This study demonstrates that liquid smoke and triticale flour effectively enhance the flavor, texture, and radical scavenging activity of goat's milk yogurt, contributing to the development of a functional and healthy yogurt product.

1. Introduction

Yogurt, a fermented milk product produced through lactose fermentation by lactic acid bacteria, has been valued for its health benefits since as early as 6000 BC. It is a rich source of protein, calcium, and essential nutrients, making it particularly beneficial for individuals with lactose intolerance and gastrointestinal disorders (Vahedi et al., 2008 and De Vrese et al., 2015). Goat milk yogurt is distinguished by its unique texture and "goaty" flavor, which is attributed to volatile compounds such as octanoic acid, setting it apart from cow or buffalo milk yogurt (Haenlein, 2004 and Park et al., 2006). The growing consumer demand for natural food additives has increased interest in alternatives such as liquid smoke (LS) and dietary fibers. Liquid smoke, produced through the pyrolysis of wood, serves as a natural preservative and flavoring agent, enhancing the safety and sensory qualities of foods like meats and cheeses (Martin et al., 2010 and Lingbeck et al., 2014). Its antimicrobial and antioxidant properties, derived from compounds such as aldehydes and phenols, make it a promising addition to dairy products (Huang et al., 2013). Simultaneously, incorporating dietary fibers into dairy products has gained popularity due to their health benefits, including improving gut health and reducing the risks of chronic diseases (Slavin, 2005 and Kim et al., 2016). Triticale, a hybrid grain derived from rye and wheat, is an excellent source of dietary fiber and phenolic compounds, contributing to its notable antioxidant capacity (Hosseinian & Mazza, 2009; Agil et al., 2016). This study aimed to assess the impact of adding varying concentrations of LS (0.02% and 0.03%) and triticale flour (TF) (1.0% and 2.0%) to goat's milk on the physicochemical and sensoryproperties of yogurt during storage.

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Understanding these effects could support the development of functional, natural yogurt products with enhanced health benefits.

2. Materials and Methods

Fresh Goat Milk: Fresh goat milk, containing 13.38% total solids, 3.97% fat, 3.45% protein, 0.80% ash, 0.17% titratable acidity, and a pH of 6.59, was sourced from the El-Serw Animal Production Research Station, Animal Production Research Institute, Agricultural Research Center (ARC), Egypt.

Starter Culture: The yogurt starter culture, comprising *Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus*, was obtained from DANISCO, Rue de Clémencières - BP 32, Sassenage, Denmark.

Triticale flour: Triticale flour was acquired from the Sakha Experimental Station, Animal Production Research Institute, ARC, Egypt.

Liquid smoke: Liquid smoke was supplied by Food Technology Research Institute, Agricultural Research Center (ARC), Egypt.

Table 1. Chemical composition of triticale flour (TF) and liquid smoke (LS)

Composition%	Triticale flour	Composition	Liquid smoke
Total Protein	8.77	Total solid %	4.37
Fat	1.71	pH	2.58
Total Carbohydrates	69.12	Titratable acidity (% acetic acid)	1.67
Fiber	11.29	Total phenol (mg GAE kg^{-1})	6579
Ash	1.90	Total carbonyl (mg kg^{-}1)	7869
moisture	7.41	Potassium sorbate (mg/mL)	0.672

Yogurt manufacture

Yogurt was prepared according to the method described by Hashim et al. (2009). The yogurt was divided into nine treatment batches as follows:

- Treatment A (Control): Yogurt made from goat's milk.
- Treatment B: Yogurt made from goat's milk with 0.02% Liquid Smoke (LS).
- Treatment C: Yogurt made from goat's milk with 0.03% Liquid Smoke (LS).
- Treatment D: Yogurt made from goat's milk with 1% Triticale Flour (TF).
- Treatment E: Yogurt made from goat's milk with 2% Triticale Flour (TF).
- Treatment F: Yogurt made from goat's milk with 0.02% LS + 1% TF.
- Treatment G: Yogurt made from goat's milk with 0.02% LS + 2% TF.
- Treatment H: Yogurt made from goat's milk with 0.03% LS + 1% TF.
- Treatment I: Yogurt made from goat's milk with 0.03% LS + 2% TF.

The yogurt samples were stored at 5 ± 1°C for 21 days.

Physicochemical analysis

Coagulation time

Coagulation time, used as an indicator of starter culture stability, was recorded as the time (in seconds) required for each milk sample to begin coagulating (El-Metwally, 2015).

Curd tension

Curd tension was measured following the method described by Ismail et al. (2015).

Curd syneresis

Curd syneresis of yogurt was determined at room temperature (25–30°C) using the method described by Mehanna and Mehanna (1989).

Additional physicochemical analysis

Total solids, Fat, Total protein, Titratable acidity and fiber content of resultant yoghurt were determined according to the method of AOAC (2012). pH values were measured using JENWAY Digital pH meter Model 3310. Total volatile fatty acids (TVFA) were determined according to Kosikowiski (1978). Viscosity of yogurt was determined according to Aryana et al. (2006). Carbohydrates content were calculated according to Abd El-Aziz et al. (2004). Total carbonyl was determined according to Endo et al. (2001).

Potassium sorbate was determined according to Sohrabvandi et al. (2015).

The total phenol compounds were determined using Zheng and Wang's (2001) method, with Folin Ciocalteu Reagent (FCR) and gallic acid as a reference solution. The antioxidant activity was evaluated in accordance with Lee et al., (1995).

Microbiological analysis

The counts of total viable bacteria and lactic acid bacteria were determined according to the methods described by the American Public Health Association (APHA, 2004). Coliform bacteria counts were assessed following the method outlined by Marshall (2004).

Sensory properties of yogurt

The sensory evaluation of yogurt was conducted by a panel of ten experts from the Dairy Science Department, El-Serw Animal Production Research Station, Animal Production Research Institute, Agricultural Research Center. Panelists evaluated the samples using a score sheet based on the criteria described by Kebary and Hussein (1999).

Statistical analysis

The collected data were statistically analyzed using SAS software (SAS, 2004) employing analysis of variance (ANOVA). When the F-test indicated significance, the least significant difference (LSD) was calculated for mean comparisons following Duncan's method (1955). All values presented in the tables represent the mean (± standard deviation) of three independent experiments.

3. Results and Discussion

Effect of adding liquid smoke (LS) or triticale flour (TF) to goat's milk on starter activity

Data presented in Table 2 illustrate the development of acidity in goat milk inoculated with a yogurt starter, influenced by the addition of TF and LS over a 180-minute incubation period. A gradual increase in titratable acidity was observed in both the control and all treated samples throughout the incubation period. Significant differences in acidity were noted among all treatments during the incubation. These findings are consistent with those of Agil (2012), who reported that the addition of triticale may enhance lactic acid production and bacterial activity, leading to increased yogurt acidity. Samples containing LS exhibited a lower rate of acidity development during the incubation period compared to the control, aligning with the results of Ismail et al. (2015). The reduced rate of acidity development in LS-treated samples can be attributed to the antimicrobial properties of smoke, as noted by Huang et al. (2011). These properties are due to the presence of carbonyl compounds, phenolic compounds, and acidic substances.

Table 2. Effect of adding liquid smoke and triticale flour to goat's milk on starter activity (clarified as acidity percentage)

Treatments	Incubation time (min)						
	0	30	60	90	120	150	180
Control	0.25	0.27	0.29	0.32	0.41	0.48	0.64
0.02 %LS	0.23	0.25	0.28	0.30	0.37	0.42	0.56
0.03 %LS	0.21	0.23	0.26	0.29	0.36	0.41	0.53
1 %TF	0.25	0.29	0.31	0.33	0.43	0.50	0.66
2 %TF	0.26	0.31	0.32	0.35	0.44	0.52	0.67
0.02 %LS+1%TF	0.24	0.26	0.28	0.31	0.39	0.45	0.57
0.02 %LS+2%TF	0.24	0.27	0.29	0.31	0.40	0.46	0.58
0.03 %LS+1%TF	0.22	0.24	0.27	0.31	0.37	0.43	0.55
0.03 %LS+2%TF	0.22	0.25	0.28	0.33	0.38	0.44	0.57
0.04 %LS+1%TF	0.20	0.23	0.25	0.28	0.36	0.42	0.52
0.04 %LS+2%TF	0.21	0.25	0.26	0.30	0.37	0.44	0.53

LS= Liquid smoke. TF= Triticale flour.

Effect of adding triticale flour (TF) or liquid smoke (LS) on coagulation time, curd tension, and curd syneresis of goat's milk

Data presented in Table 3 illustrate the effect of adding TF or LS on the coagulation time, curd tension, and curd syneresis of goat's milk. The results clearly show that the addition of TF significantly influenced the starter's coagulation time. Furthermore, as the concentration of TF increased, curd tension also increased. Curd syneresis, defined as the liquid separation from yogurt, is a critical quality indicator for yogurt. The results revealed that syneresis values decreased as the concentration of TF increased. This reduction in syneresis can likely be attributed to the increased total solids in the yogurt resulting from TF addition. These findings are consistent with the results of Nouri et al. (2011). According to Agil et al. (2012), TF is a rich source of proteins, lipids, phenols, dietary fibers, carbohydrates, starch, and ash, which may contribute to its effect on yogurt quality. The addition of LS also significantly affected the starter's coagulation time, resulting in an extended coagulation process. This elongation may be due to the antimicrobial properties of LS, which can influence starter activity (Ismail et al., 2015). Conversely, the addition of LS decreased the curd tension of goat's milk, likely due to its inhibitory effects on the yogurt culture, which weakened the resulting curd structure (El-Metwally, 2015). Interestingly, LS increased curd syneresis when added to the milk. During the incubation period, syneresis values increased across all treatments, with a slightly higher rate observed in the first 30 minutes (El-Metwally et al., 2021). Additionally, it was noted that when LS was added at higher levels (0.04%), the aroma and taste of the yogurt were negatively affected. The reduction in syneresis observed with higher TF concentrations may be attributed to the fiber's ability to absorb whey released by the gel structure, retaining more water (Garcia-Perez et al., 2005). Common factors contributing to syneresis include prolonged incubation times, an unbalanced whey protein-to-casein ratio, low total solid content, and physical mishandling of the product during distribution and storage (Mwizerwa et al., 2017).

Table 3. Effect of adding liquid smoke and triticale flour on coagulation time, curd tension and curd syneresis of goat's milk.

Treatments	Starter Coagulation time (hrs)	Curd tension (g)	Curd syneresis (gm/15 gm of curd)*			
			Time (min)			
			10	30	60	120
Control	3.10^{a}	30.21^{d}	3.322^{e}	3.989^{e}	5.878^{a}	6.589^{e}
0.02 %LS	3.15^{a}	30.14^{d}	3.341^{d}	3.996^{d}	5.885^{a}	6.599^{d}
0.03 %LS	3.20^{a}	30.07^{d}	3.349^{c}	4.011^{c}	5.914^{a}	6.622^{c}
1 %TF	3.00^{b}	32.14^{abc}	2.984^{h}	3.812^{h}	5.533^{b}	6.016^{h}
2 %TF	3.00^{b}	32.61^{a}	2.975^{i}	3.801^{i}	5.511^{b}	5.987^{j}
0.02 %LS+1%TF	3.05^{a}	32.09^{abc}	3.358^{b}	4.211^{b}	5.927^{a}	6.643^{b}
0.02 %LS+2%TF	3.05^{a}	32.51^{ab}	2.993^{fg}	3.817^{h}	5.542^{b}	6.026^{g}
0.03 %LS+1%TF	3.10^{a}	32.02^{bc}	3.363^{b}	4.217^{ab}	5.936^{a}	6.652^{ab}
0.03 %LS+2%TF	3.10^{a}	32.44^{abc}	2.989^{gh}	3.824^{g}	5.533^{b}	5.998^{i}
0.04 %LS+1%TF	3.25^{c}	31.97^{c}	3.371^{a}	4.223^{a}	5.942^{a}	6.660^{a}
0.04 %LS+2%TF	3.25^{c}	32.29^{abc}	2.997^{f}	3.838^{f}	5.546^{b}	6.103^{f}
LSD	0.393***	0.529***	0.006***	0.006***	0.099***	0.009***

Significant different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc
*Whey excluded (grams) from 15 gm of curd kept at room temperature after 10, 30, 60 and 120min.
= Triticale flour LS= Liquid smoke.

Physicocheimcal of yoghurt

The pH and acidity of the experimental yogurt treatments and the control showed significant differences ($p < 0.05$), as shown in Table 4. Yogurt made from milk containing LS exhibited significantly lower acidity ($p < 0.05$) and higher pH values ($p < 0.05$) compared to the control. In fresh samples, the acidity values were 0.81%, 0.75%, 0.72%, 0.84%, and 0.85% for the control, B, C, D, and E treatments, respectively. This reduction in acidity in LS-treated samples can be attributed to the antibacterial properties of liquid smoke, which is effective against spoilage and pathogenic bacteria (Holley and Patel, 2005). The antibacterial action of LS is primarily due to compounds such as phenols, carbonyls, and organic acids (Vitt et al., 2001). In contrast, adding TF to milk significantly increased ($p < 0.05$) the acidity and lowered the pH values. The increased acidity in yogurt containing TF may result from the enhanced bacterial activity, leading to higher lactic acid production (Agil, 2012). Grains, such as triticale, provide essential nutrients for lactic acid biosynthesis. Nikoofar et al. (2013) similarly observed higher acidity in yogurt containing grains compared to the control. As reported by Attia et al. (2023), titratable acidity increases consistently during storage, while pH decreases in all yogurt treatments. Vasiljevic et al. (2007) also found that the addition of oat β-glucan to yogurt promotes the synthesis of lactic and propionic acids. For formulating healthy food, triticale bran offers natural prebiotics (Agil et al., 2012). During storage, all yogurt treatments exhibited a significant increase in titratable acidity ($p < 0.005$), with an inverse relationship between acidity and pH. These results align with those of Ismail et al. (2016) and Khairi et al. (2020).

Total solids (T.S%) and total protein (T.P %) of yogurt

Table 4 shows the T.S. and T.P. % values in fresh samples and during storage were comparable for the control and LS-treated samples (B and C). However, the addition of TF significantly increased ($p<0.05$) both T.S. and T.P. % values as the concentration of TF increased. This increase can be attributed to the higher T.S. and T.P. levels present in TF (Fraś et al., 2016). In fresh yogurt samples, the T.S. and T.P.% values were 13.77% and 3.63% for the control (A), 13.74% and 3.62% for treatment B, 13.73% and 3.61% for treatment C, 13.94% and 3.68% for treatment D, and 14.02% and 3.69% for treatment E. Throughout the storage period, all treatments exhibited a significant increase ($p < 0.05$) in T.S. and T.P. values, likely due to moisture loss during storage. These findings are consistent with those reported by Farag et al. (2007), Arslan and Bayrakci (2016), and El-Metwally et al. (2021). Triticale, like wheat and other cereals, is a rich source of protein and has a high lysine content, which contributes to the increased T.P. levels observed in TF-containing yogurt (Agil and Hosseinian, 2014).

Fat and TVFA values of yogurt

As shown in Table 4, the fat (FAT) and total volatile fatty acid (TVFA) values in the control and treatments with liquid smoke (LS) alone (B and C) differed significantly ($p < 0.05$) at zero time and throughout the storage period. Treatments containing LS exhibited the lowest TVFA values, which can be attributed to the beneficial effects of smoke components on the activity of starter bacteria (Ismail et al., 2015). Furthermore, the FAT and TVFA values increased significantly ($p < 0.05$) over the storage period. A similar significant increase ($p < 0.05$) was observed as the concentration of triticale flour (TF) increased, particularly in treatments D, E, F, G, H, and I. These results align with the findings of Ismail et al. (2015) and El-Metwally et al. (2021). At zero time, the TVFA value for the control was 7.89%. This value increased to 8.15%, 8.18%, 8.08%, and 8.11% for treatments D, E, F, and G, respectively. The addition of triticale bran contributed to these changes, as its polysaccharide extracts are known to exhibit in vitro antioxidant activity, likely due to the presence of bound phenolic compounds (Agil and Hosseinian, 2012).

Table 4. Effect of adding liquid smoke or triticale flour to goat's milk on some physicocheimcal values of yoghurt, during storage

Treatments	Acidity %					pH				
	Storage Periods (days)					Storage Periods (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
A	0.81±0.01^{bd}	0.90±0.09^{bc}	1.12±0.01^{bb}	1.29±0.01^{ab}	1.030^{b}	4.56 ±0.01^{ac}	4.50±0.1^{bc}	4.46±0.01^{cc}	4.30±0.02^{cd}	4.45^{c}
B	0.75±0.01^{dd}	0.86±0.01^{cd}	1.06±0.01^{bd}	1.14±0.02^{ad}	0.954^{d}	4.72±0.02^{aab}	4.56±0.01^{abb}	4.48±0.01^{abc}	4.32±0.01^{abd}	4.52^{ab}
C	0.72±0.06^{de}	0.81±0.01^{cf}	1.03±0.01^{bf}	1.09±0.01^{af}	0.921^{e}	4.78±0.01^{aa}	4.56±0.02^{ab}	4.47±0.01^{ac}	4.36±0.01^{ad}	4.54^{a}
D	0.84±0.01^{abd}	0.92±0.01^{abc}	1.14±0.03^{abb}	1.33±0.01^{aab}	1.060^{ab}	4.61±0.01^{acd}	4.49±0.01^{bcd}	4.43±0.02^{ccd}	4.28±0.01^{cdd}	4.45^{cd}
E	0.85±0.01^{ad}	0.94±0.03^{ac}	1.16±0.01^{ab}	1.35±0.02^{aa}	1.075^{a}	4.55±0.01^{ad}	4.47±0.01^{bd}	4.40±0.1^{cd}	4.23±0.01^{dd}	4.41^{d}
F	0.77±0.02^{cdd}	0.87±0.02^{ccd}	1.09±0.01^{bcd}	1.16±0.01^{acd}	0.973^{cd}	4.66±0.01^{aab}	4.57±0.01^{abb}	4.36±0.01^{abc}	4.41±0.01^{abd}	4.5^{ab}
G	0.79±0.01^{cd}	0.88±0.01^{cc}	1.12±0.01^{bc}	1.19±0.01^{ac}	0.996^{c}	4.64±0.02^{abc}	4.51±0.01^{bbc}	4.45±0.01^{bcc}	4.37±0.01^{bcd}	4.49^{bc}
H	0.75±0.01^{dd}	0.84±0.01^{cd}	1.06±0.01^{bd}	1.17±0.01^{ad}	0.955^{d}	4.71±0.01^{aa}	4.60±0.1^{ab}	4.47±0.02^{ac}	4.38±0.01^{ad}	4.54^{a}
I	0.77±0.01^{cdd}	0.86±0.01^{ccd}	1.10±0.01^{cd}	1.18±0.01^{acd}	0.978^{cd}	4.68±0.02^{aab}	4.58±0.01^{abb}	4.47±0.01^{abc}	4.37±0.01^{abd}	4.52^{ab}
Mean	0.788± 0.01^{d}	0.875±0.01^{c}	1.099±0.01^{b}	1.212±0.01^{a}		4.65^{a}	4.53^{b}	4.44^{c}	4.33^{d}	
	TS%					TP%				
A	13.77±0.02^{dd}	13.95±0.01^{cd}	14.16±0.01^{bd}	14.37±0.01^{ad}	14.06^{d}	3.63±0.01^{bd}	3.68±0.02^{bc}	3.70±0.02^{bb}	3.73±0.02^{ab}	3.68^{b}
B	13.74±0.02^{dd}	13.98±0.01^{cd}	14.14±0.01^{bd}	14.35±0.02^{ad}	14.05^{d}	3.62±0.01^{bd}	3.67±0.1^{bc}	3.70±0.01^{bb}	3.72±0.01^{ab}	3.68^{b}
C	13.73±0.01^{dd}	13.96±0.01^{cd}	14.11±0.01^{bd}	14.33±0.02^{ad}	14.03^{d}	3.61±0.01^{bd}	3.66±0.01^{bc}	3.69±0.01^{bb}	3.72±0.01^{ab}	3.67^{b}
D	13.94±0.02^{bd}	14.31±0.1^{bc}	14.40±0.01^{bb}	14.79±0.02^{a}	14.36^{b}	3.68±0.01^{ad}	3.74±0.01^{ac}	3.78±0.01^{ab}	3.81±0.01^{aa}	3.73^{a}
E	14.02±0.01^{ad}	14.36±0.01^{ac}	14.47±0.01^{ab}	14.88±0.01^{aa}	14.43^{a}	3.69±0.01^{ad}	3.75±0.01^{ac}	3.78±0.01^{ab}	3.80±0.01^{aa}	3.74^{a}
F	13.91±0.01^{bcd}	14.30±0.02^{bcc}	14.37±0.02^{bbc}	14.77±0.02^{abc}	14.33^{bc}	3.68±0.01^{ad}	3.74±0.01^{ac}	3.79±0.02^{ab}	3.81±0.01^{aa}	3.73^{a}
G	14.00±0.1^{ad}	14.34±0.01^{ac}	14.44±0.01^{ab}	14.86±0.01^{aa}	14.41^{a}	3.70±0.1^{ad}	3.75±0.02^{ac}	3.79±0.01^{ab}	3.82±0.01^{aa}	3.74^{a}
H	13.89±0.01^{cd}	14.270.02±^{cc}	14.35±0.02^{bc}	14.76±0.01^{ac}	14.31^{c}	3.69±0.01^{ad}	3.75±0.02^{ac}	3.77±0.02^{ab}	3.82±0.01^{aa}	3.74^{a}
I	13.97±0.01^{bcd}	14.24±0.02^{bcc}	14.41±0.01^{bbc}	14.73±0.02^{abc}	14.33^{bc}	3.71±0.01^{ad}	3.76±0.02^{ac}	3.78±0.02^{ab}	3.83±0.1^{aa}	3.75^{a}
Mean	13.88^{d}	14.19^{c}	14.32^{b}	14.64^{a}		3.66^{d}	3.71^{c}	3.74^{b}	3.76^{a}	
	FAT%					TVFA%				
A	4.22±0.01^{ad}	4.38±0.01^{ac}	4.53±0.01^{ab}	4.67±0.01^{aa}	4.45^{a}	7.89±0.01^{cd}	8.65±0.01^{cc}	8.98±0.01^{bc}	9.51±0.01^{ac}	8.75^{c}
B	4.21±0.01^{abd}	4.37±0.02^{abc}	4.51±0.01^{abb}	4.66±0.01^{aab}	4.43^{ab}	7.83±0.01^{cd}	8.60±0.02^{c}	8.93±0.1^{bc}	9.45±0.02^{ac}	8.72^{c}
C	4.21±0.01^{abcd}	4.36±0.01^{abcc}	4.51±0.01^{abbc}	4.65±0.04^{aabc}	4.42^{abc}	7.80±0.02^{cd}	8.57±0.01^{c}	8.90±.01^{bc}	9.41±0.02^{ac}	8.69^{c}
D	4.18±0.01^{abcd}	4.34±0.01^{abcc}	4.49±0.01^{abbc}	4.64±0.01^{aabc}	4.41^{abc}	8.15±0.01^{abd}	8.82±0.01^{abc}	9.29±0.01^{ab}	9.74±0.01^{ab}	8.97^{ab}
E	4.17±0.02^{abcd}	4.34±0.02^{abcc}	4.48±0.01^{abbc}	4.63±0.02^{aabc}	4.4^{abc}	8.18±0.02^{ad}	8.91±0.01^{ac}	9.36±0.01^{ab}	9.81±0.01^{a}	9.03^{a}
F	4.18±0.01^{abcd}	4.34±0.01^{abcc}	4.50±0.02^{abbc}	4.64±0.02^{aabc}	4.41^{abc}	8.08±0.01^{bd}	8.76±0.01^{bc}	9.20±0.01^{b}	9.71±0.02^{ab}	8.9^{b}
G	4.17±0.02^{cd}	4.33±0.02^{cc}	4.49±0.01^{bc}	4.63±0.1^{ac}	4.38^{c}	8.11±0.01^{abd}	8.78±0.01^{abc}	9.24±.001^{ab}	9.73±0.01^{ab}	8.96^{ab}
H	4.17±0.01^{abcd}	4.34±0.01^{abcc}	4.49±0.01^{abbc}	4.64±0.01^{aabc}	4.41^{abc}	8.05±0.01^{abd}	8.71±0.01^{abc}	9.17±0.02^{ab}	9.68±0.01^{ab}	8.95^{ab}
I	4.16±0.01^{bcd}	4.33±0.01^{bcc}	4.48±0.01^{bbc}	4.62±0.01^{abc}	4.39^{bc}	8.07±0.01^{bd}	8.75±0.01^{bc}	9.20±0.01^{b}	9.69±0.01^{ab}	8.94^{b}
Mean	4.18^{d}	4.34^{c}	4.49^{b}	4.62^{a}		8.01^{d}	8.72^{c}	9.16^{b}	9.64^{a}	

Significant different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc

*Treatment A: Yoghurt made from goat's milk (control),Treatment B: Yoghurt made from goat's milk contained 0.02 % LS, Treatment C: Yoghurt made from goat's milk contained 0.03 % LS, Treatment D: Yoghurt made from goat's milk contained 1 % TF, Treatment E: Yoghurt made from goat's milk contained 2 % TF.Treatment F: Yoghurt made from goat's milk contained 0.02 % LS+1% TF,Treatment G: Yoghurt made from goat's milk contained 0.02 % LS+2 % TF, Treatment H: Yoghurt made from goat's milk contained 0.03 % LS+1 % TF, Treatment I:Yoghurt made from goat's milk contained 0.03 % LS+2 % TF.

Changes of viscosity (CP) and water holding capacity of yogurt

The data presented in Table 5 revealed that the viscosity and water holding capacity of yogurt were significantly influenced (p ≤ 0.05) by both LS and TF additions. Sodini et al. (2004) clarified that the main factors affecting yogurt's viscosity include hydrocolloids, protein and fat content, heat treatment, the combination of lactic acid bacteria used, the rate of acidification, and the storage duration. According to Viuda-Martos et al. (2010), fiber can be utilized to enhance several functional qualities, including texture, oil and water holding capacity, emulsification, gel formation, and as a bulking agent in reduced-sugar applications, as well as extending the shelf life of processed foods. In the control, the fresh yogurt's viscosity (CP) and water-holding capacity values were 1355 and 88.25, respectively. For treatments D, E, F, G, H, and I, these values increased to 1516, 96.45; 1533, 99.16; 1512, 96.38; 1526, 99.10; 1508, 96.33; and 1503, 98.88%, respectively. These findings align with those of Lim (2018) and Ahmed et al. (2010), who observed that the organic acids produced by the LAB and β-glucan in oat slurry significantly improved the viscosity and water-binding ability of synbiotic yogurt.Hashim et al. (2009) found that adding 0.5% oat β-glucan, inulin, and guar gum improved serum retention and viscoelastic properties in yogurt. Fibers can enhance the texture and reduce syneresis of yogurt by increasing water-holding capacity, stabilizing high-fat yogurt, enhancing viscosity, and forming gels (Balthazar et al., 2016; Dello Staffolo et al., 2017). β-glucan, a form of dietary fiber found in triticale grain, may produce high-viscosity solutions in the human gut, which is beneficial to health. For this reason, it is added to foods (El Khoury et al., 2012).

Table 5. Effect of adding liquid smoke and triticale flour to goat's milk on viscosity (CP) and water holding capacity of yoghurt

Treatments*	Viscosity (CP)			Water holding capacity %		
	Storage Periods (days)					
	0	21	Mean	0	21	Mean
A	1355±2.0^{f}	711±2.2^{f}	1033^{f}	88.25±0.01^{f}	90.11±0.01^{f}	89.18^{f}
B	1350±2.5^{fg}	704±1.7^{fg}	1027^{fg}	88.19±0.01^{fg}	90.05±0.01^{fg}	89.12^{fg}
C	1347±2.1^{g}	700±2.5^{g}	1023^{g}	88.13±0.01^{g}	89.97±0.01^{g}	89.04^{g}
D	1516±1.5^{c}	882±2.0^{c}	1199^{c}	96.45±0.01^{d}	98.23±0.01^{d}	97.34^{d}
E	1533±1.5^{a}	896±2.2^{a}	1215^{a}	99.16±0.01^{a}	101.34±0.01^{a}	100.25^{a}
F	1512±1.0^{cd}	878±1.9^{cd}	1195^{cd}	96.38±0.01^{de}	98.17±0.01^{de}	97.27^{de}
G	1526±1.5^{b}	893±2.2^{b}	1209^{b}	99.10±0.01^{b}	101.29±0.01^{b}	100.19^{b}
H	1508±1.0^{de}	875±2.2^{de}	1192de	96.33±0.01^{e}	98.14±0.01^{e}	97.23^{e}
I	1503±2.5^{e}	871±2.1^{e}	1939^{e}	98.88^{c}±0.01	101.0±0.01^{c}	99.94^{c}
Mean	1461±1.3^{b}	8233±1.6^{a}		1063±0.01^{b}	9647±0.01^{a}	

*See Table 4.
Significan t different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc

Changes in dietary fibers, phenolic content, total antioxidant activity and carbohydrates of yoghurt at zero time

Table 6 shows that treatments B and C, which only included LS, had no fibers as a control. Additionally, the control and LS-containing treatments (B and C) had comparable carbohydrate contents. Nevertheless, the phenolic content and total antioxidant activity have been significantly (p<0.05) raised by the addition of LS. Dietary fibers, phenolic content, total antioxidant activity, and carbohydrate contents rose significantly (p<0.05) when TF was added at various amounts. These outcomes concur with those published by Atwaa et al. (2020) and Mohamed et al. (2014). According to Alqahtani et al. (2021) there is a correlation between the dairy product's antioxidant properties and phenolic concentration.

Staffolo et al., (2004) employed apple, wheat, bamboo, and inulin as sources of dietary fiber to improve the rheological qualities of yoghurt. Hosseinian and Mazza (2009) and Fraś et al., (2016), cleared that triticale is high in phenolics and dietary fibers, including both soluble and insoluble fibers.

Variations in amounts of carbohydrates between treatments may be the cause of coagulum variation besides pH lowering caused by the synthesis of organic acids, such as lactic acid (Hashim et al., 2009). Fardet, (2010) showed that whole grain consuming has been linked to a number of health advantages due to its bioactive contents, specifically fiber and phytochemicals. Whole-grain phenolic acids exhibit anticancer, antibacterial, antioxidant, and anti-inflammatory effects (Shahidi and Yeo, 2018).

Table 6. Effect of adding liquid smoke and triticale flour to goat's milk on dietary fibers, phenolic content, total antioxidant activity and Carbohydrates of yoghurt at zero time

Treatments*	Dietary fibers%	Phenolic content**	Total antioxidant activity***	Carbohydrates%
A	---	47.21±0.01^{g}	14.12±0.01^{i}	3.54±0.01^{c}
B	---	91.54±0.02^{d}	42.23±0.01^{f}	3.55±0.01^{c}
C	---	98.14±0.03^{c}	47.09±0.01^{e}	3.56±0.01^{c}
D	0.22±0.01^{b}	71.64±0.02^{f}	31.24±0.03^{h}	6.48±0.01^{b}
E	0.30±0.01^{a}	79.30±0.1^{e}	34.31±0.01^{g}	6.60±0.1^{ab}
F	0.22±0.01^{b}	99.65±0.01^{b}	49.52±0.01^{d}	6.50±0.1^{ab}
G	0.29±0.01^{a}	99.71±0.01^{ab}	52.44±0.02^{c}	6.61±0.01^{ab}
H	0.23±0.01^{b}	99.77±0.02^{a}	56.72±0.02^{b}	6.53±0.01^{ab}
I	0.29±0.01^{a}	99.81±0.02^{a}	60.14±0.03^{a}	6.62±0.01^{a}
LSD	0.033***	0.109***	0.057***	0.138***

*See table 4. **Data expressed as mg gallic acid equivalent (GAE)/g dry weight.
***Data expressed as µmol Trolox equivalent (TE)/g dry weight.
-Significant different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc

Changes in microbial counts of yogurt during refrigerated storage for 21 days

Table 7 shows that treatments with LS alone (B and C) had significantly lower (p<0.05) total viable bacterial and lactic acid bacteria counts compared to the control. Adding TF at varied levels significantly enhanced these values. Our findings were consistent with those of Hamdy et al. (2021). Total viable bacterial and lactic acid bacteria counts increased significantly (p<0.05) until the 7th day of storage, then decreased significantly (p<0.05) until the final week of the storage period. This could be due to increased acidity production, which may inhibit bacterial growth during storage. These findings are in agreement with those reported by Dabija et al. (2018) and Saleh et al. (2019). Varlet et al. (2010) reported that phenolic compounds have both antibacterial and antioxidant functions, and they also contribute to the smoky flavor of liquid smoke. According to Aportela-Palacios et al. (2005), the presence of dietary fiber in yogurt samples greatly boosts bacterial growth. No coliform bacteria were present, in all treatments, during the storage period. This could be attributed to the hygienic conditions maintained during processing and storage (El-Metwally et al., 2021). Anggraini and Yuniningsih (2013) discovered that phenols are active ingredients capable of providing antibacterial and antimicrobial effects in liquid smoke, while Milly et al. (2005) confirmed that smoke utilization, in addition to imparting flavor, color, and aroma to foods, has been used for food preservation due to its antimicrobial and antioxidant effects. According to Perez and Saura (2005), soluble dietary fibers in triticale flour may serve dual functions in the gastrointestinal tract: acting as prebiotics, enhancing the survival of gut bacteria, and serving as antioxidants released by the grain matrix, particularly after colonic fermentation.

Table 7. Effect of adding liquid Smoke and triticale flour to goat's milk on some microbial groups (log cfu/ml) of yoghurt

Storage period (days)	A	B	C	D	E	F	G	H	I	Mean
	Treatments*									
	Total viable bacterial									Mean
0	8.66^{bbc}	8.40^{bcd}	8.27^{abb}	8.73^{bbc}	8.77^{ab}	8.61^{bb}	8.67^{be}	8.51^{bd}	8.60^{abb}	8.58^{b}
7	9.04^{abc}	8.81^{acd}	8.67^{aab}	9.10^{abc}	9.14^{aa}	8.99^{ab}	9.01^{ae}	8.85^{ad}	8.91^{aab}	8.91^{a}
14	8.26^{bcc}	8.09^{ccd}	7.92^{abc}	8.37^{bcc}	8.41^{ac}	8.28^{bc}	8.32^{ce}	8.16^{cd}	8.25^{abc}	8.23^{c}
21	8.11^{bcd}	7.85^{cdd}	7.61^{abd}	8.16^{bcd}	8.20^{ad}	8.08^{bd}	8.11^{de}	8.01^{dd}	8.04^{abd}	8.02^{d}
Mean	8.45^{bc}	8.38^{cd}	8.53^{ab}	8.49^{bc}	8.63^{a}	8.51^{b}	8.12^{e}	8.28^{d}	8.52^{ab}	
	Lactic acid bacteria									Mean
0	8.54^{abb}	8.24^{bbc}	8.06^{abb}	8.06^{abb}	8.62^{ab}	8.52^{abb}	8.55^{bd}	8.44^{bcd}	8.51^{abb}	8.45^{b}
7	8.93^{aab}	8.66^{abc}	8.61^{aab}	8.61^{aab}	9.02^{aa}	8.88^{aab}	8.91^{ad}	8.73^{acd}	8.91^{aab}	8.85^{a}
14	8.14^{abc}	7.95^{bcc}	7.77^{abc}	7.77^{abc}	8.27^{ac}	8.16^{abc}	8.19^{cd}	8.03^{ccd}	8.11^{abc}	8.09^{c}
21	7.98^{abd}	7.72^{bcd}	7.44^{abd}	7.44^{abd}	8.07^{ad}	7.92^{abd}	7.96^{dd}	7.89^{cdd}	7.95^{abd}	7.88^{d}
Mean	8.37^{ab}	8.27^{bc}	8.41^{ab}	8.37^{ab}	8.49^{a}	8.47^{ab}	7.97^{d}	8.14^{cd}	8.39^{ab}	
	Coliform									
0	0	0	0	0	0	0	0	0	0	
7	0	0	0	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	
21	0	0	0	0	0	0	0	0	0	

*See Table 4.

-Significant different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc

Sensory evaluation

Table 8 shows that adding LS or TF resulted in the highest total scores for yogurt. The addition of LS had no significant effect on color and appearance or the body and texture, but it significantly improved ($P < 0.05$) the flavor. Adding TF resulted in a slight reduction in color and appearance but significantly enhanced the body, texture, and flavor of the resultant yogurt ($P < 0.05$). The highest marks were to treatments B, G, and I. Martín-Diana et al. (2003) found that goat's milk yogurt had the least favorable flavor and appearance due to its liquid texture and unique taste. Over the course of the storage period, the total score for yogurt in all treatments slightly decreased (Walkunde et al., 2008, and Tonguc et al., 2013). The main products of wood pyrolysis are organic acids, carbonyls, and phenols, which give liquid smoke its distinctive flavor, color, and antibacterial properties (Jody et al., 2014). Yogurt boosted with insoluble dietary fibers from triticale (IDFT) was classified as "excellent" based on the overall sensory quality scores, which is essential for the food market (Miocinovic et al., 2018).

Table 8. Effect of adding liquid smoke and triticale flour to goat's milk on organoleptic properties of yoghurt

Storage period	A	B	C	D	E	F	G	H	I	Mean
	*Treatments									
	Color &Appearance (15)									
0	14^{a}	14^{a}	13^{ab}	12^{abc}	12^{ac}	12^{abc}	12^{ac}	12^{ac}	12^{ac}	12.59±1.21^{a}
7	14^{ab}	13^{ab}	13^{ab}	12^{abc}	11^{abc}	12^{abc}	11^{abc}	11^{abc}	11^{abc}	12±1.20^{ab}
14	13^{abc}	13^{abc}	12^{abc}	11^{bc}	11^{bc}	11^{bc}	11^{bc}	11^{bc}	10^{bcc}	11.44±1.22^{bc}
21	13^{ac}	12^{ac}	12^{abc}	11^{bc}	10^{c}	11^{bc}	10^{c}	10^{cc}	10^{cc}	11±1.21^{c}
Mean	13.5±1.1^{a}	13±1.1^{a}	12.5±1.1^{ab}	11.58±1.^{bc}	11±1.10^{c}	11.5±1.1^{bc}	11±1.13^{c}	11±1.1^{c}	10.75±1^{c}	
	Body &Texture(35)									Mean
0	32^{ab}	32^{ab}	32^{ab}	33^{ab}	34^{a}	33^{aab}	34^{a}	33^{ab}	34^{aa}	33±1.24^{a}
7	32^{ab}	31^{b}	31^{b}	32^{ab}	33^{ab}	32^{bab}	33^{ba}	32^{ab}	33^{ba}	32.11±1.23^{b}
14	31^{ab}	31^{b}	31^{b}	32^{ab}	32^{ab}	32^{bab}	32^{ab}	31^{ab}	32^{ba}	31.55±1.22^{b}
21	31^{abc}	30^{cb}	30^{bc}	31^{abc}	32^{ac}	30^{cab}	31^{ca}	30^{abc}	31^{ca}	30.66±1.24^{bc}
Mean	31.5±1.14^{ab}	31±1.2^{b}	31±1.21^{b}	32±1.34^{ab}	32.7±1.3^{a}	31.75±1.4^{ab}	32.5±1.3^{a}	31.5±1.3^{ab}	32.5±1.4^{a}	
	Flavour (50)									Mean
0	41^{ae}	46^{abc}	45^{ac}	43^{ad}	44^{ad}	46^{aab}	47^{aa}	46^{abc}	46^{abc}	44.88±1.27^{a}
7	41^{ae}	46^{abc}	45^{ac}	43^{ad}	43^{ad}	46^{ab}	47^{aa}	45^{abc}	46^{abc}	44.65±1.27^{a}
14	40^{be}	45^{abc}	44^{bc}	42^{bd}	42^{bd}	46^{ab}	46^{ab}	45^{bc}	45^{abc}	43.87±1.21^{b}
21	40^{be}	44^{abc}	43^{bc}	42^{bd}	41^{bd}	45^{ab}	46^{ab}	44^{bc}	45^{abc}	43.33±1.26^{b}
Mean	**40.5±1.52^{e}**	45.2±1.5^{abc}	44.25±1.5^{c}	42.5±1.52^{d}	42.5±1.5^{d}	45.75±1.5^{ab}	46.5±1.5^{a}	45±1.5^{bc}	45.5±1.5^{abc}	

*See Table 4.
-Significant different at p > .(0.001*** ,0.01** ,0.05*) For each effect the different letters in the means the multiple comparisons are different from each. Letter a is the highest means followed by b, c …..etc

4. Conclusion

The findings of this study highlight the potential of liquid smoke and triticale flour as natural additives to enhance the physicochemical and sensory qualities of goat's milk yogurt. Their incorporation improved yogurt texture, flavor, and antioxidant properties, making them promising ingredients for developing functional dairy products. These results can be particularly useful for dairy manufacturers looking to meet the growing consumer demand for natural and health-enhancing food products. Future research could explore optimizing the concentrations of LS and TF for different dairy applications, investigating long-term storage effects, and assessing consumer acceptance on a larger scale. Additionally, exploring the potential probiotic benefits and interactions with different bacterial cultures would further enhance the understanding of their functional properties

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