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Fundamental Elements to Produce Sesame Yoghurt from Sesame Milk

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Abstract: Problem statement: In previous work sesame milk was developed. The developed milk had slightly acceptable flavor and limited shelf life. Fermentation of sesame milk is one way to overcome these problems. **Approach:** Sesame yoghurt experiments were carried out using pasteurized sesame milk (75°C for 5 min) with 14% initial sesame seed concentration and 2.7% glucose with different dairy products: lactose, Cheese Dried Whey (CDW), Non Fat Dried Milk (NFDM) and skim milk. The formulas were fermented using commercial yoghurt starter culture for different times. **Results:** The texture of all resulted yoghurt lacked the typical set yoghurt body and was similar to that of drinking yoghurt. The best formula was sesame milk with 2% CDW followed by sesame milk with 2% NFDM and then by sesame milk extended with skim milk in a ratio of 1:1. The optimum fermentation times were 6, 8 and 8 h respectively. **Conclusion/Recommendations:** The addition of dairy products was essential to promote acid and flavor development.

Key words: Sesame milk, sensory properties, skim milk, dairy products, flavor development, yoghurt starter, starter culture, drinking yoghurt, acid production

INTRODUCTION

In our attempts to utilize decortictated sesame seed in production of imitated dairy products, sesame milk was successfully developed (Quasem *et al*., 2009). Unfortunately, the developed milk had slight flavor acceptability; additionally the developed milk had limited shelf life. One way to improve the quality of the developed milk is by fermentation. Since fermentation often improves flavor and texture of vegetable milks, attempts had been made to develop fermented products from vegetable milks (Beuchat and Nail, 1978; Rao *et al*., 1988; Cheng *et al*., 1990). In addition to soymilk, attempts were done to produce yoghurt from peanut milk (Beuchat and Nail, 1978; Bucker *et al*., 1979), cowpeas and mung beans (Rao *et al*., 1988) and winged beans (Miyamoto *et al*., 1987; Rao *et al*., 1988).

Considerable research had been undertaken to study the fermentability and acid development in vegetables milk, especially soymilk inoculated with different yoghurt cultures. Researches demonstrated the need for vegetable milk supplementation to enhance the activity and acid production of inoculated yoghurt cultures. This is due to the low concentration of sugars (Shirai *et al*., 1992b) and other substrates needed by the yoghurt cultures (Karleskind *et al*., 1991). Considerable effort had been directed to investigate the effect of the following supplements, alone or in combination with other additives, on acid development in vegetables milk: sucrose (Chopra *et al*., 1984; Miyamoto *et al*., 1987; Yazici *et al*., 1997; Trindade *et al*., 2001); glucose (Bucker *et al*., 1979; Pinthong *et al*., 1980; Yazici *et al*., 1997); fructose (Buono *et al*., 1990; Yazici *et al*., 1997); lactose (Beuchat and Nail, 1978;

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Miyamoto *et al*., 1987; Cheng *et al*., 1990); Non Fat Dry Milk (NFDM) (Rao *et al*., 1988; Buono *et al*., 1990; Lee *et al*., 1990; Karleskind *et al*., 1991); cheese whey (Beuchat and Nail, 1978; Karleskind *et al*., 1991; Shirai *et al*., 1992b); yeast extract (Bucker *et al*., 1979; Pinthong *et al*., 1980); buffalo milk; Skim milk (Chopra *et al*., 1984; Miyamoto *et al*., 1987); evaporated milk (Buono *et al*., 1990); caseinate; casein hydrolyzate; whey protein hydrolyzate (Granata and Morr, 1996); and whey protein concentrate (Lee *et al*., 1990; Karleskind *et al*., 1991). It has been reported that L. bulgaricus did not grow without fortification in soymilk (Pinthong *et al*., 1980; Rao *et al*., 1988). Not all yoghurt cultures can ferment sucrose (Rao *et al*., 1988); therefore the selection of sugar is very important. Despite of using fortifiers, some workers reported inability of yoghurt cultures to produce adequate lactic acid in soy yoghurt (Cheng *et al*., 1990; Lee *et al*., 1990; Karleskind *et al*., 1991).

In addition to supplements, processing conditions, also, affect the fermentability and acid production. For instance, it had been reported that heat treatment of soymilk; processing factors (variety of soybean, soaking, cooking, blanching, defatting of soybean and using soy protein isolates rather than whole soybeans) (Rao *et al*., 1988; Karleskind *et al*., 1991; Granata and Morr, 1996); and total solids in soymilk (Chang and Stone, 1990); and fortification with calcium (Yazici *et al*., 1997), also affect the fermentability and acid development of soymilk.

The aim of this research was to investigate the fermentability and quality of sesame milk prepared with different fortifiers, inoculated with starter culture and incubated for different times.

MATERIALS AND METHODS

Sesame seed: Decorticated sesame seed (originated from Ethiopia) were used. It was obtained from Al-Kasih Factories Group for Food Stuff in Zarqqa/ Jordan and characterized as sweet sesame (bitter taste was absent).

Sesame milk: Sesame milk was prepared according to the procedure described by Quasem *et al*. (2009) using 14% initial concentration of sesame seed (sesame seeds: water ratio).

Starter culture: Commercial (YC-380) Direct-Vat-Set yoghurt culture (DVS) composed of Streptococus thermophilus and Lactobacillus delbruekii subsp. Bulgaricus was used. The starter culture preparation and inoculation procedure were done according to the manufacturer recommendations (Chr. Hansen Denmark).

Other materials: Non-Fat Dried Milk (NFDM) (Regilait, France); UHT skim milk (Hammodah, Jordan); full fat milk (University of Jordan Dairy Plant, Jordan); cheese whey powder (KemFuds, Mexico); glucose (Panreac, Spain).

Sesame yoghurt preparation steps: Eleven sesame milk formulas were prepared (Table 1). Sesame milk from each formula was filled in eight 50 mL presterilized test tubes (50 g sesame milk per test tube). Formulated sesame milks were pasteurized at 75°C-5 min, cooled to 43°C, inoculated with starter culture and incubated at 43°C for different periods: 4, 6 and 8 h. Direct-vat-set yoghurt culture was prepared according to the manufacturer instructions.

At the end of each incubation period, two test tubes from each formula were stored refrigerated to be tested in the next day for titratable acidity and expert panel sensory evaluation. Tubes (representing all formulas) assigned for microbial analysis were incubated for 8 h.

Table 1: Sesame milk formulas used to prepare sesame youghurt

Treatment	Treatment number	Sesame milk (initial percentage of sesame seed was 14%) with Ingredients	Grams
No additives	1	Sesame milk	100.0
	Dextrose	2.7	
Lactose	2	Sesame milk	100.0
	Dextrose	2.7	
	Lactose	2.0	
Skim milk	3	Sesame milk	75.0
	Dextrose	2.1	
	UHT skim milk	25.0	
4	Sesame milk	50.0	
	Dextrose	1.4	
	UHT skim milk	50.0	
NFDM	5	Sesame milk	100.0
	Dextrose	2.7	
	NFDM	1.0	
6	Sesame milk	100.0	
	Dextrose	2.7	
	NFDM	2.0	
7	Sesame milk	100.0	
	Dextrose	2.7	
	NFDM	4.0	
Dried whey	8	Sesame milk	100.0
	Dextrose	2.7	
	Dried whey	1.0	
9	Sesame milk	100.0	
	Dextrose	2.7	
	Dried whey	2.0	
10	Sesame milk	100.0	
	Dextrose	2.7	
	Dried whey	4.0	
Cow's Milk	11	-	100.0

Treatments evaluation: The treatments were evaluated according to the following quality parameters:

- Measuring the pH every 1 h during the incubation period (8 h). Titratable acidity was determined after 4, 6 and 8 h from the incubation time by titrating samples with 0.1N NaOH.
- Counting the lactic acid bacteria after 8 h of fermentation for selected treatments.
- Sensory evaluation for all treatments using expert panel test , samples were mixed before evaluation.

Statistical analysis: All statistical analyses were carried out using SAS (SAS Institute Inc., Cary, USA, Release 8.02, 2001). Comparisons of means with respect to the influence of different milk formula and different incubation time were carried out using the GLM procedure considering a completely randomized design. The LSD-test was employed in order to maintain an experimentwise of 5% (Steel and Torrie, 1969).

RESULTS

Proximate composition of sesame milk formulas: The proximate composition of sesame milk formulated products ranged between 11.64-17.75 total solids, 2.97-4.37 protein, 3.25-6.49 fat, 0.48-0.82 ash, 0-2.96 lactose and 3.72-7% carbohydrates (Table 2). The full fat cow's milk proximate composition was 11.68% total solids, 3.22% protein, 3.25% fat, 0.69% ash, 4.52% lactose and 4.52% carbohydrates. It can be seen that the protein content of all formulas are almost similar to that of cow's milk (except treatments with 2 or 4% NFDM), whereas fat content of most formulas were about double that of full fat milk except sesame milk formulas number 3 and 4 due to the replacement of part of sesame milk with skim cow's milk.

Rate of pH reduction and acid production: The rate of pH drop during the lactic acid fermentation of 10 sesame milk formulas in addition to a sample of full fat cow's milk as control treatment were presented in Fig. 1 and Table 3. The pH decreased with increasing the fermentation time for all milk formulas. Sesame milk with glucose had the lowest pH drop rate (Fig. 1 and Table 3) and acid production rate (Fig. 2 and Table 3) throughout the fermentation time (8 h). After four h. of fermentation, most of the milk formulas had pH values below 4.5 (0.54-0.80% titratable acidity) except formula number 1 composed of sesame milk and glucose (0.33% titratable acidity), which took 6 h to reach a pH value below 4.6 (0.44% titratable acidity). At the end of the fermentation time, formula number 1 (composed of sesame milk with added glucose) had the highest pH value (4.38) and the lowest titratable acidity (0.52%), while other milk formulas had pH values ranged between 3.66-4.04 and the titratable acidity values ranged between 0.72- 1.00%. The control treatment that composed of full fat cow's milk and sesame milk with added NFDM (2 or 4%), had the highest titratable acidity value (~1.00%). This value is followed by ~0.86% for sesame milk with the addition of 2 or 4% dried whey and by ~0.75% for sesame milks extended with skim milk or sesame milk with added lactose.

Table 2: Calculated* proximate composition of different milk formulas used for sesame yoghurt preparations

Formula**	Formula number	Total solids (%)	Protein (%)	Fat (%)	Ash (%)	Added dextrose (%)	Lactose (%)	Total Carbohydrates (%)
Sesame milk	1	13.91	2.97	6.43	0.48	2.70	-	4.04
Sesame with 2% lactose	2	15.91	2.97	6.43	0.48	2.03	2.00	6.04
1:3 ratio of skim milk and sesame milk	3	12.32	3.07	4.84	0.61	1.35	1.24	3.27
1:1 ratio of skim milk and sesame milk	4	11.64	3.17	3.26	0.68	2.70	2.48	4.50
Sesame milk with 1% NFDM	5	14.87	3.32	6.44	0.56	2.70	0.52	4.56
Sesame milk with 2% NFDM	6	15.83	3.67	6.44	0.64	2.70	1.04	5.08
Sesame milk with 4% NFDM	7	17.75	4.37	6.49	0.80	2.70	2.08	6.12
Sesame milk with 1% dried whey	8	14.88	3.10	6.44	0.56	2.70	0.74	4.78
Sesame milk with 2% dried whey	9	15.85	3.23	6.45	0.65	2.70	1.48	5.52
Sesame milk with 4% dried whey	10	17.67	3.49	6.47	0.82	2.70	2.96	7.00
Full fat Cow's milk	11	11.68	3.22	3.25	0.69	-	4.52	4.52

*: Using the proximate composition of sesame milk (with 14% initial sesame seed concentration) and other added ingredients proximate composition as reported by USDA (2003). ** All sesame milk in all formulas contained 2.7% glucose

Table 3: Acid production and pH reduction during lactic acid fermentation of different sesame milk formulas

	Fermentation time												
					4 h			6 h			8 h		
	Treat	0	1h	2 h	3 h			5 h			7 h		
Treatment*	number	pH	pH	pH	pH	pH	TA	pH	pH	TA	pH	pH	TA
Sesame milk	1	6.51d	6.31 d	5.96 a	5.45 a	4.87 a	0.33 g	4.71 a	4.58 a	0.44 f	4.48 a	4.38 a	0.52 e
Sesame milk + 2.7% lactose	2	6.53 d	6.19 e	5.30 cd	4.60 e	4.34 i	0.55 ef	4.21 ef	4.10 cd	0.64 e	4.02 cd	3.99 b	0.72 d
1:3 ratio of skim milk and sesame milk	3	6.76 a	6.50 b	5.21 def	4.69 d	4.39 efg	0.61 d	4.23 de	4.09 cd	0.74 bc	4.00 d	3.92 b	0.76 cd
1:1 ratio of skim milk and sesame milk	4	6.66 b	6.58 a	5.57 b	4.78 c	4.44 cd	0.59 de	4.24 cde	4.10 cd	0.74 bc	4.03 cd	3.92 cb	0.75 cd
Sesame milk + 1% NFDM	5	6.59 c	6.36 cd	5.33 c	4.77 c	4.48 c	0.54 f	4.36 b	4.20 b	0.66 de	4.12 b	4.04 b	0.77 cd
Sesame milk + 2% NFDM	6	6.58 c	6.32 d	5.17 f	4.67 d	4.42 de	0.66 bc	4.28 c	4.11 c	0.77 b	4.00 d	3.94 b	0.98 a
Sesame milk + 4% NFDM	7	6.60 c	6.40 c	5.29 cde	4.82 c	4.48 c	0.77 a	4.34 b	4.20 b	0.85 a	4.13 b	4.00 b	1.00 a
Sesame milk + 1% dried whey	8	6.37 e	6.05 f	5.20 ef	4.65 ed	4.42 ed	0.62 cd	4.19 f	4.06 ed	0.70 dc	3.99 d	3.95 b	0.78 c
Sesame milk + 2% dried whey	9	6.22 f	5.98 g	5.16 f	4.64 ed	4.36 hig	0.64 bcd	4.14 g	4.07 cde	0.78 b	3.98 d	3.66 c	0.85 b
Sesame milk + 4% dried whey	10	6.16 g	6.03 fg	5.19 f	4.69 d	4.41 def	0.69 b	4.25 cd	4.09 cd	0.77 b	4.07 cb	3.96 b	0.87 b
Milk 11	6.49 d	6.39 c	5.89 a	5.04 b	4.38 fgh	0.80 a	4.17 fg	4.04 e	0.87 a	4.00 d	3.92 bc	1.00 a	

*: Sesame milk in all formulas contains 2.7% glucose. Means within columns followed by the same letter do not differ significantly (p<0.05)

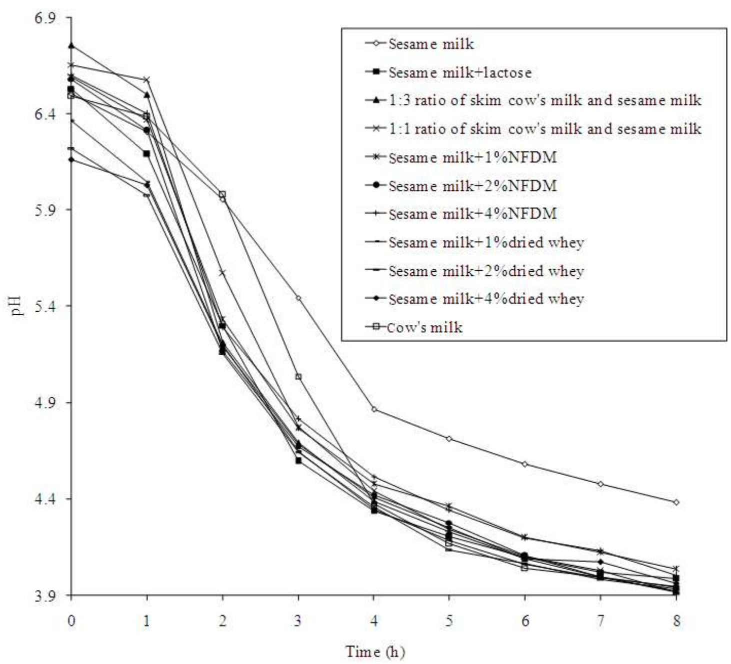

Fig. 1: PH fermentation profile of different sesame milk formulas during the fermentation. Sesame milk in different formulas contains 2.7% glucose

Lactic Acid Bacterial count (LAB): The lactic acid bacteria counts ($\log_{10}$ CFU/mL) for the six milk formulas under investigation are shown in Fig. 3. The highest bacterial count was found in the formula based on cow's milk, while the lowest one was for that based on sesame milk with added glucose. Addition of dairy products to sesame milk, significantly increased the count of lactic acid bacteria but with varying degrees. The most effective dairy products in this regard were NFDM followed by dried whey and then by sesame milk extended with skim cow's milk (in a ratio of 1:1) or sesame milk with added lactose.

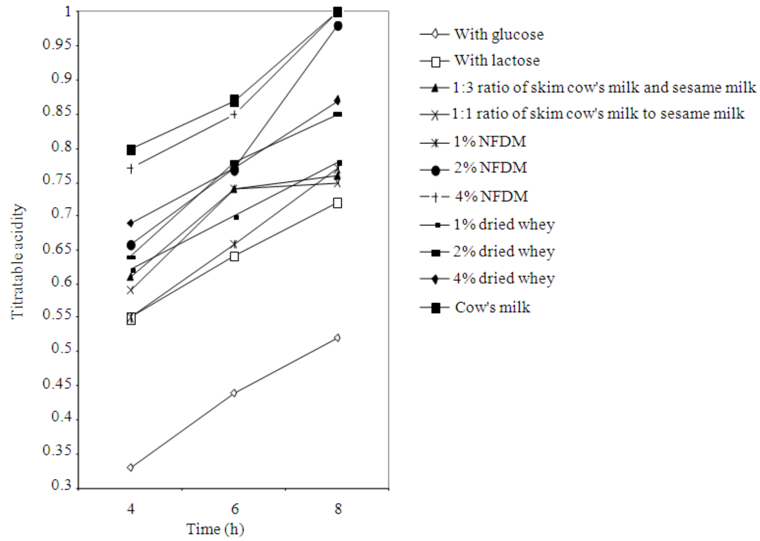

Fig. 2: Rate of acid production during fermentation of different sesame milk formulas

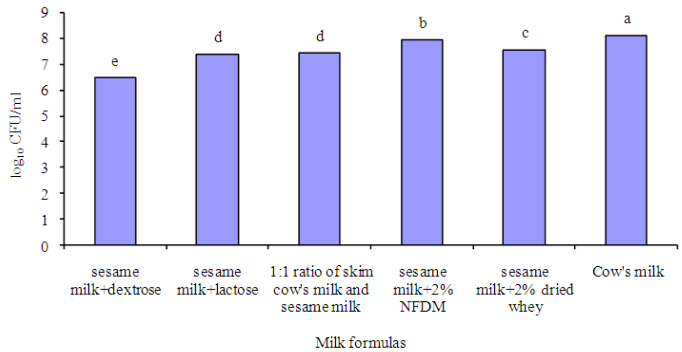

Fig. 3: lactic acid bacteria count ($\log_{10}$ CFU/mL) of sesame yogurt prepared from six sesame milk formulas after eight hours of fermentation. Values with different letter are significantly different at $p<0.05$ according to LSD test according to LSD test

Sensory evaluation: Expert panel sensory evaluation revealed that all the produced yoghurt lack the typical set yoghurt texture and appear more likely as yoghurt drink.

All samples with the addition of whey powder resulted in problems related to dispersion stability and color. In these samples, phase separation was characterized by the formation of two layers (the lower serum layer and the upper dispersed layer). In terms of color, the addition of dried whey imparted yellow coloration of the produced yoghurt. However, this color did not imposed a problem that negatively affected their acceptability by the panel test participants.

Fermentation by lactic acid bacteria improved the flavor of sesame milk (reduced undesirable sesame flavor) with varying degrees for all formulas. Sesame with added glucose produced yoghurt that lacked the typical yoghurt flavor. Addition of dairy products improved the flavor and the most effective dairy products in this regard were cheese whey powder followed by NFDM, while the least effective one was lactose. However, the addition of NFDM and dried whey at levels above 2% resulted in unacceptable flavor. Additionally, it has been noticed that sesame flavor decreased with increasing the fermentation time for all treatments.

DISCUSSION

Yoghurt was defined as the coagulated milk formed by a cultured fermentation. The product is usually resulted from fermenting fortified milk with a mixed starter culture consisting of Streptococcus thermophilus and Lactobacillus delbruckii subsp. Bulgaricus (Schmidt *et al*., 1980).

Pasteurized sesame milk produced in this study had a limited shelf life and sensory acceptability (Quasem *et al*., 2009). The Lactic acid fermentation was used in this study as one approach to prolong the shelf life of the product. Additionally, the produced flavor compounds and acids during fermentation may mask the undesirable flavors in sesame milk and consequently increasing their sensory acceptability.

Fermentability of sesame milk: Yoghurt starter culture had very complex nutritional requirements; milk supplies them with all of their nutrients such as carbon source (lactose), amino acids (from proteins), vitamins and minerals. In this study, the starter culture used did not grow well in sesame milk with added 2.7% glucose, since they have the lowest rate of pH drop (Fig. 1) and acid production (Fig. 2) and the lowest microbial count after 8 h of fermenting period (Fig. 3). Thus, it was concluded that sesame milk with added glucose did not contains adequate amounts of potentially essential nutrients for the growth of the starter culture used. Accordingly, different dairy products were added to stimulate the production of acid and flavor compounds. It was found that the addition of 2% lactose increased the acidity, which indicated the preference of the used starter culture for lactose rather than glucose.

Other dairy products used in this study (NFDM and dried whey in levels of 2%) improved both acid production and flavor development. The variations in the percentages of titratable acidity between different sesame milk formulas are partly related to the variation in buffering capacity. The LAB count (Fig. 3) demonstrated the effectiveness of different dairy products used in this study in promoting the growth of lactic acid bacteria. Unexpectedly, sesame milk with added NFDM or dried whey (in levels of 2 or 4%) promotes more microbial growth (Fig. 3) and consequently more acid production than sesame milk supported by skim milk (Fig. 2). However, more experiments are needed to clarify this result. The lactic acid fermentation behavior of sesame milk observed in this study is consistent with that of other vegetable milks. Shirai *et al*. (1992b) reported that it is difficult to obtain a product with the same nutritional and organoleptic qualities as true yoghurt from soymilk alone.

Effect of lactic acid fermentation on sensory attributes of the produced yogurt: Lactic acid fermentation of sesame milk improved the flavor acceptability (as indicated by the expert panels sensory evaluation. The resulted yoghurt texture (which is similar to yoghurt drink) is similar to that reported for soymilk yoghurt. For instance, Shirai *et al*. (1992a) reported that soy proteins are unable to coagulate properly by acid development in order to produce a food with a texture similar to that of true yoghurt. However, Granata and Morr (1996) demonstrated the role of soymilk solids (soy solids with the addition of cheese whey solids) in texture development due to fermentation and they found that the optimum soy solids ranged between 15-17%. In this study, the sesame solids used seems to be not enough to develop the desired texture of the produced yoghurt. The phase separation in yoghurt formulated with added dried cheese whey in this study was also reported by Karleskind *et al*. (1991) and Beuchat and Nail (1978) using soymilk and peanut milk respectively with the addition of dried cheese whey.

Sesame milk formulas number 4 (with skim milk in 1:1 ratio) and number 6 (with 2% NFDM) resulted in yoghurt with texture similar to that of drinking yoghurt with no need to further improve their quality as a drinking yogurt. Formula number 9 (formulated with dried whey) had more sensory acceptability than the other two formulas (number 4 and 6). However the problem of phase separation can negatively affect its acceptability as yoghurt drink.

CONCLUSION

The study revealed the possibility of producing sesame yoghurt. Sesame milk did not have the gelation ability needed for the formation of gel. Addition of dairy products (particularly NFDM and dried whey) is essential to stimulate acid and flavors production during fermentation of sesame milk by yoghurt culture. Fermentation time play a role in determining the acceptability of the produced yoghurt. Further studies are needed to:

- Evaluate the protein quality of the produced products and to investigate the effect of different processing condition on it
- Determine the factors affecting the gelation of sesame milk proteins
- Evaluate the effect of using different starter cultures on the quality of the produced yoghurt

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