Color parameters and rheological properties of Rayeb milk made from cow milk and quinoa milk mixture

BY

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Abstract:

The aim of this study was to prepare a bio-fermented milk product (Rayeb milk) with high nutritional and health benefits. Five various samples of Rayeb milk were manufactured as follow: T1 from cow milk, T2 from quinoa milk, T3 from cow and quinoa milk mixture (50%:50%), T4 from cow and quinoa milk mixture (75%:25%) and T5 from cow and quinoa milk mixture (25%:75%). ABT-5 culture was used as starter culture. The results showed that mixing of quinoa milk with cow milk stimulated starter bacteria during fermentation period. Rayeb contained quinoa milk had higher acidity and total protein/DM and lower moisture and Fat/DM values than those of cow milk Rayeb. Values of $L*$ and $b*$ slightly decreased whereas $a*$ values slightly increased in Rayeb produced using quinoa and cow milk mixtures. The addition of quinoa milk to cow milk led to reduction in serum separation and syneresis levels. Apparent viscosity, yield stress and consistency coefficient values increased while plastic viscosity and flow behavior index values lowered in quinoa milk Rayeb. On the basis of the obtained results, it can be concluded that Rayeb milk made with 25 or 50% quinoa milk have better rheological characteristics than that of control Rayeb.

Keywords: Rayeb milk, Quinoa milk, color, syneresis, viscosity

Introduction

Rayeb milk, also known as Laban rayeb, is one of the most produced and consumed fermented dairy products in Egypt and Arab countries. Rayeb milk is made in the traditional way in rural regions, with continues natural fermentation. Now, in specialized dairy plants in Arab world, Rayeb milk is made from pasteurized cow's milk with using probiotic cultures, resembling bio-stirred yoghurt in the developed countries (Bouton et al. 2002).

On the other hand, non-dairy milk alternatives are water extracts of pseudocereals or grains and have grown in popularity for human nutrition. The global market for these products has turned into a multi-billion-dollar business over the years, and it is expected to reach a value of around 26 billion USD in the next five years (Tangyu et al. 2019). Because of their excellent health advantages, such as their influence in controlling diabetes and hypertension, researchers have been keen to incorporate pseudocereals like quinoa in the food industry. Farajzadeh et al. (2020) recorded that the quinoa seeds are an appropriate alternative candidate of nutrients with high phenolic and flavonoid components and antimicrobial and antioxidant activities. Quinoa seeds are suitable as alternative functional sources of nutrients with high biological effects for human nutrition because of their high protein, carbohydrate, ash, fibre, iron, total phenol and flavonoid contents, low saponin concentration, and significant antibacterial and antioxidant effects. Unfortunately, consumption of quinoa is not spread worldwide because of absence of information regarding nutritional and health benefits of quinoa among consumers.

Textural characteristics of fermented milk products like thickness, smoothness, viscosity, and structural resistance to stress are important properties to assess the acceptance of consumer. Now these attributes are associated with some health benefits (Behare et al. 2010). Several attempts have been used to improve the quality of the texture of fermented milk (yoghurt), such as increasing the solids in milk (adding fat, proteins, or sugars such as sucrose and fructose), addition of stabilizers (pectin, starch, alginate, and gelatin) (Lee and Lucey 2010) and using exopolysaccharide producing lactic acid bacteria (Han et al. 2016). Concerning Rayeb milk, Abou-Dobara et al. (2017) used oat milk to improve chemical, textural and health properties of Rayeb made from cow milk. In similar trend, Ismail et al. (2020) utilized sesame milk in Rayeb milk preparation. Therefore, the goal of this work was to investigate the possibility of using quinoa milk in improvement of textural and health attributes of bio-Rayeb milk.

Materials and methods

Materials

Fresh raw cow milk (acidity 0.17 %, pH 6.61, total solids 13.03, fat 4.3 and total protein 3.38%) was obtained from EL-Serw Animal Production Research station, Animal Production Research Institute, Agriculture Research center, Egypt. Quinoa seeds were obtained from the Egyptian Company for Natural Oils, Cairo, Egypt. ATB-5 culture which consists of *streptococcus thermophilus, Lactobacillus acidophilus and Bifidobacterium bifidum* was obtained from Chr. Hansen, lab A/S Copenhagen, Denmark.

Methods

Preparation of quinoa milk

The quinoa seeds were carefully purified from impurities, then soaked in pre-boiled water for 24 hours at 25 ^{o}c. Water was changed every 8 hours. The seeds were grinded with water by blender (1 seeds:6 water *w/v*). The resulted quinoa milk heated to 90^{o}c for 10 min then cooled to 40^{o}c. The chemical composition of quinoa milk was as follow: acidity 0.23 %, PH 5.92, total solids 16.20, fat 5.2 and total protein 4.93%

Preparation of Bio- Rayeb milk

Five treatments of Rayeb milk were made from cow and quinoa milk mixture as follow:

Treatment 1 (T1): Rayeb from 100% cow milk

Treatment 2 (T2): Rayeb from 100% quinoa milk

Treatment 3 (T3): Rayeb from 50% cow milk + 50% quinoa milk

Treatment 4 (T4): Rayeb from 75% cow milk + 25% quinoa milk

Treatment 5 (T5): Rayeb from 25% cow milk + 75% quinoa milk

After heating to 90°C for 10 min, cow milk and quinoa milk were immediately cooled to 40°C. For samples 3, 4 and 5, quinoa milk was mixed with cow milk then all milk samples were inoculated with ABT-5 cultures (0.1 g/L of milk), incubated at 40°C for fully coagulation and stored at 4°C overnight. Once blended for five min and divided to three parts transferred to three jars which preserved at 4°C for 14 days. Rayeb milk samples were analyzed when fresh and after 7 and 14 days of refrigerated storage. Three replicates of each treatment were conducted.

Chemical analysis

AOAC (2000) methods had been used to determine titratable acidity, total solids, fat and total nitrogen contents of samples. The pH values were estimated using a pH meter (Corning pH/ion analyzer 350, Corning, NY) after calibration with standard buffers (pH 4.0 and 7.0).

Color measurements

The color of fresh Rayeb milk was measured using Hunter Colorimeter Model D2s A-2 (Hunter Assoc. Lab. Inc. Va, USA) following the instruction of the manufacturer (Hunter colorimeter, 1976).

Rheological properties measurements

Syneresis of Rayeb samples was measured according to the modified method of Guzman-Gonzalez et al. (2000). Approximately 5.0 g Rayeb sample was placed in a pre-weighed tube and centrifuged for 10 min at 3000× g and 4 °C. The amount of supernatant whey was recorded. The percentage synaeresis was calculated using the equation below:

Syneresis (%) = Total weight of drained whey (g) ×100/ Total weight of yoghurt (g)

For determination of serum separation, Rayeb samples were placed in 50 ml graded cylinders. After storage for 14 days at 4°C, the volume of the layer of clear serum at the top was recorded as an indication of instability. The percentage serum separation was calculated using the equation below:

Serum separation (%) = The volume of the layer of clear serum at the top (ml) x 100/50

Viscosity was measured after 24 hr at 25 ºC ± 0.5 at 50rpm using RV spindle No.3 (DV-II + Viscometer Brookfield Engineering Labs. Inc. Middle Boro, MA02346, USA).

Statistical analysis

The data were statistically analyzed by SPSS statistical 22.0 using two-way ANOVA to assess the significant differences between the means of samples and storage period. The means of results were compared by the Tukey test at a significance level of 5% ($p < 0.05$). All data were expressed as mean ± standard deviation of three replicates.

Results and Discussion

Starter activity in mixture of cow milk and quinoa milk during fermentation period

For determination of ABT culture activity in cow milk and quinoa milk mixtures, the changes of pH values in milk inoculated with ABT culture were monitored at 30 min intervals till 180 min. Results were introduced in Fig. 1.

As it is expected, a continuous reducing in pH values in all Rayeb samples were noticed during fermentation period. The changes in pH values could be attributed to the number and/or metabolic activity of acid producing micro-organisms. As starter grows, it produces acid which causes a decrease in pH. These results are in agreement with those previously stated for Rayeb milk (Abou-Dobara et al. 2017).

Mixing of cow milk with quinoa milk caused a pronounced decrasing in pH values, also, an increase in the levels of added quinoa milk positively affected the rate of acid production. The drop in pH was faster within fermentation in quinoa milk or cow and quinoa milk mixture than that of control. This might be due to the stimulation of starter bacteria by the quinoa which acted as prebiotic. Codină et al. (2016) showed that yogurt treatments fortified with quinoa flour presented a much higher reduce in the pH value and a much higher increase in the total acidity value comparatively with the non- fortified control sample during the fermentation stage. This fact is generally obvious in treatments with the greatest levle of the quinoa flour. These data suggest that quinoa flour affected the growth of yogurt starter culture and, as a result, the production of lactic acid. High amino acids and mineral contents of the quinoa flour are necessary for the growth of yogurt starter culture. Ramírez-Rojas et al. (2018) found that the addition of quinoa to kefir resulted in a significant decrease in pH and fermentation time. This is due to the activated effect of quinoa proteins on the microflora growth.

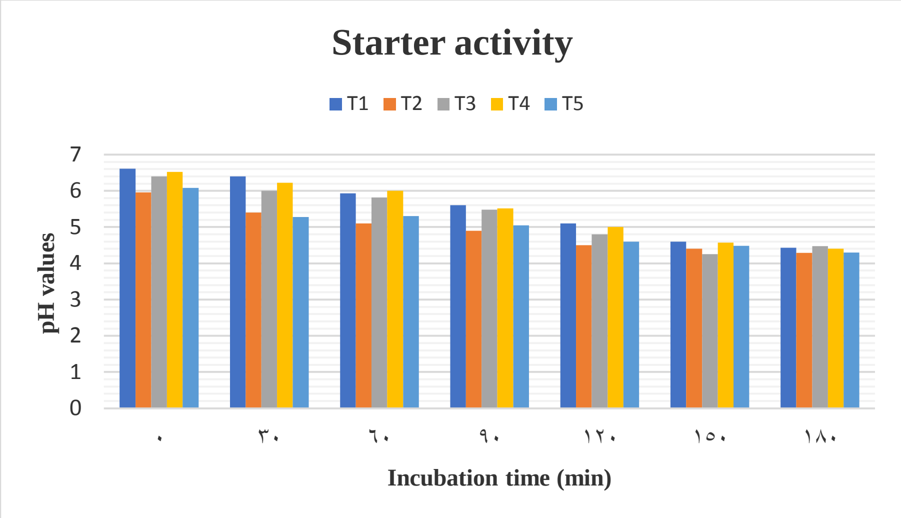

Fig. 1 Changes in pH values during fermentation of cow milk and quinoa milk mixtures

Chemical composition of Rayeb milk

Results in Table 1 clear some chemical attributes of Rayeb milk during storage period. Rayeb prepared from quinoa milk (T2) or a combination of quinoa milk and cow milk (T3, T4, and T5) exhibited greater acidity values than the cow milk control (T1). Furthermore, the increasing levels of acidity during storage were more noticeable in Rayeb contained quinoa milk. According to Codina et al. (2016), adding quinoa flour to yoghurt causes an increase in acidity and a decrease in pH values. In the same trend, Mabrouk and Effat (2020) found that adding quinoa flour up to 1% to yoghurt resulted in an increase in acidity and a decrease in pH values. Generally, the titratable acidity values gradually increased within cold storage in different Rayeb milk samples which may be due to lactose fermentation and producing lactic and acetic acid.

Table 1 Chemical properties of Rayeb milk made from mixture of cow and quinoa milk

	Treatments	Storage period (day)			
		1	7	14	Means ± SD
Acidity %	T1	0.60±0.1	0.80±0.01	1.02±0.01	0.80±0.19^{C}
	T2	0.73±0.01	0.95±0.05	1.18±0.10	0.95±0.20^{A}
	T3	0.68±0.01	0.89±0.01	1.12±0.01	0.89±0.19^{B}
	T4	0.65±0.01	0.84±0.01	1.05±0.05	0.85±0.18^{C}
	T5	0.70±0.05	0.92±0.02	1.14±0.12	0.91±0.19^{B}
	Means ± SD	0.67±0.06^{c}	0.88±0.06^{b}	1.09±0.08^{a}	
Moisture %	T1	85.42±0.40	85.40±0.10	85.39±0.01	85.40±0.21^{A}
	T2	82.76±0.80	82.78±0.01	82.75±0.05	83.40±0.30^{CD}
	T3	83.93±0.03	83.90±0.10	83.85±0.10	83.89±0.08^{C}
	T4	84.67±0.10	84.61±0.01	84.60±0.01	84.63±0.06^{B}
	T5	83.33±0.01	83.35±0.02	83.40±0.10	83.99±0.95^{A}
	Means ± SD	84.22±1.04^{a}	84.00±0.95^{a}	83.99±0.95^{a}	
Fat / DM %	T1	85.42±0.40	85.40±0.10	85.39±0.01	85.40±0.21^{A}
	T2	82.76±0.80	82.78±0.01	82.75±0.05	83.40±0.30^{CD}
	T3	83.93±0.03	83.90±0.10	83.85±0.10	83.89±0.08^{C}
	T4	84.67±0.10	84.61±0.01	84.60±0.01	84.63±0.06^{B}
	T5	83.33±0.01	83.35±0.02	83.40±0.10	83.99±0.95^{A}
	Means ± SD	84.22±1.04^{a}	84.00±0.95^{a}	83.99±0.95^{a}	
TP/ DM %	T1	33.54±1.0	33.42±0.1	34.15±0.1	33.70±0.61^{B}
	T2	36.08±0.01	36.35±0.1	36.34±0.01	36.25±0.14^{A}
	T3	36.09±0.01	36.58±0.1	36.16±0.01	36.28±0.23^{A}
	T4	34.44±1.20	33.79±1.7	33.57±0.07	34.71±1.41^{C}
	T5	36.29±0.01	36.28±0.02	36.69±0.01	36.42±0.20^{A}
	Means ± SD	35.55±1.20^{a}	35.48±1.41^{a}	35.38±1.31^{a}	

^{abcd} letters indication to significant differences between the samples of Rayeb ±SD; ^{ABCD} letters indication to significant differences between storage period of Rayeb ±SD; T1: Rayeb from 100% cow milk; T2: Rayeb from 100% quinoa milk; T3: Rayeb from 50% cow milk + 50% quinoa milk; T4: Rayeb from 75% cow milk + 25% quinoa milk; T5: Rayeb from 25% cow milk + 75% quinoa milk

Utilization of quinoa milk in Rayeb manufacture lowered moisture and Fat/DM contents. On the contrary, total protein/DM values were significantly (P< 0.05) higher in quinoa Rayeb milk recorded 33.54, 36.08, 36.09, 34.44 and 36.29% in T1, T2, T3, T4 and T5 respectively at the beginning of storage period. In all Rayeb milk treatments, moisture, Fat/DM and TP/DM values were nearly constant during storage period.

Color parameters of Rayeb milk

The color scale of fermented milk products is critical in determining the consumer's level of acceptability. The effect of Rayeb milk fortification with quinoa milk on color parameters are displayed in Table 2. Rayeb milk color was significantly (P< 0.05) affected by incorporation of quinoa milk. The quinoa milk Rayeb (T2) had a dark color whereas cow milk Rayeb (T1) had a wight yellowish color (natural color of cow milk). Because *L** values indicate the degree of lightness, sample T1 had higher *L** values (87.38) as compared with sample T2 (71.9). Mixing quinoa milk with cow milk (T3, T4 and T5) led to slight reduces in the lightness of the prepared Rayeb. As the added quinoa milk level increased, the *L** values of Rayeb decreased further. As it is known, *a**-values in Hunter's color scale refers to the changes in levels of redness and greenness. The *a**-values of Rayeb milk showed a gradual and consistent increases with corresponding rises of added quinoa milk. Control sample (T1) had the lowest *a**-value while quinoa treatment (T2) possessed the highest which means that the rate of redness was increased owing to increases in total solids in Rayeb milk. Regarding the *b**-values, they denote the degrees of yellowness (+*b**-values) and blueness (-*b**-values). As expected, supplementation of Rayeb with quinoa milk caused a lowering tendency of yellowness. Among all the samples, control treatment had the highest *b**-value. Abd- Rabou et al. (2020) noted that kishk containing quinoa treatments were possessed a lower color score because of the dark color of quinoa, yet acceptable.

Table 2 Color parameters ($L*$, $a*$, $b*$) of fresh Rayeb milk

Treatments	Color parameters			
	L^*	a^*	b^*	ΔE
T1	87.38±0.1[a]	-3.82±0.02[a]	13.98±0.10[a]	14.16±1.0[c]
T2	71.90±0.1[c]	-2.84±0.10[c]	12.22±0.02[b]	19.84±1.0[a]
T3	83.82±0.02[ab]	-3.30±0.10[b]	13.52±0.10[a]	14.04±0.1[c]
T4	85.14±0.07[ab]	-3.06±0.10[b]	13.64±0.10[a]	14.22±0.22[b]
T5	79.52±1.0[b]	-2.96±0.10[d]	12.58±0.10[a]	15.69±0.20[c]

[abcd] letters indication to significant differences between the samples of Rayeb ±SD; T1: Rayeb from 100% cow milk; T2: Rayeb from 100% quinoa milk; T3: Rayeb from 50% cow milk + 50% quinoa milk; T4: Rayeb from 75% cow milk + 25% quinoa milk; T5: Rayeb from 25% cow milk + 75% quinoa milk

Serum seperation and syneresis of Rayeb milk

Serum separation is a common phenomenon happening in acidified dairy drinks and results in the sedimentation of large particles at the bottom or the formation of a serum layer at the top due to aggregation and sedimentation of casing particles during storage (Kiani et al. 2008). Results of serum separation of Rayeb milk after 14 days of cold storage and syneresis of fresh Rayeb are illustrated in Fig. 2. When quinoa milk was added to cow milk, serum separation was reduced compared to the control sample, possibly due to an increase in total solid content that inhibited whey drainage. Rayeb syneresis levels also decreased with the addition of quinoa milk to cow milk. Tang et al. (2015) detailed that quinoa protein has water holding capacity (WHC) higher than that of oat, soybean, and wheat proteins, subsequently it is expected that quinoa will improve textural characteristics in a variety of food applications. Contrary to the results of this study, Codina et al. (2016) reported that a higher level of whey is detcted in yogurt treatments with a higher content of quinoa flour, most likely because quinoa flour particles damaged the continuity of protein gel network.

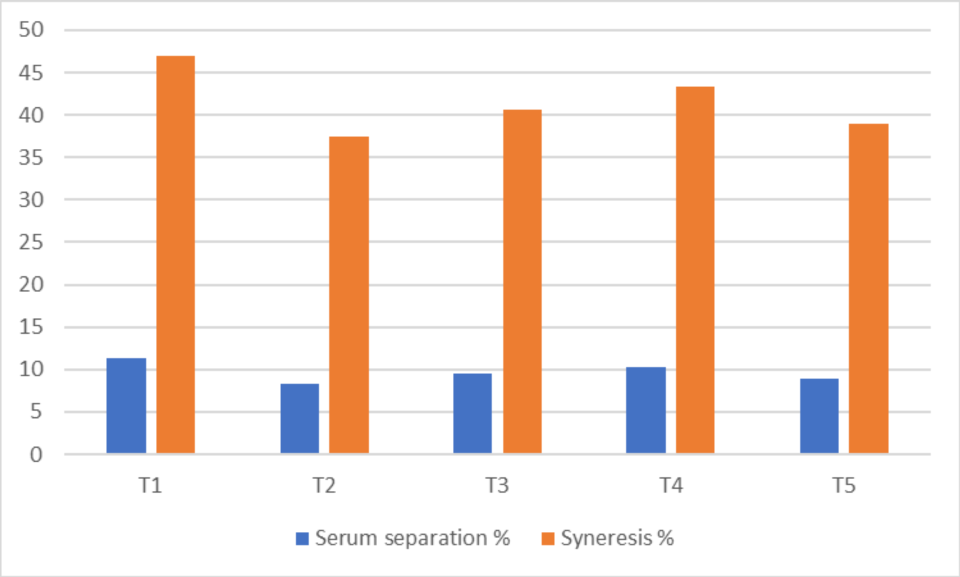

Fig. 2 Serum seperation and syneresis of Rayeb milk

Rheological charactristics of Rayeb milk

Outcomes of apparent viscosity, plastic viscosity**,** yield stress, consistency coefficient and flow behavior index of Rayeb milk during cold storgae are illustrated in Table 3. Highest apparent viscosity value was obtained for quinoa milk Rayeb (T2) whereas the lowest one was recorded for Rayeb made from cow milk (T1). The mixtures were in between both. The apparent viscosity of Rayeb was increased with increasing levels of added quinoa milk. This can be attributed to a number of factors, the first of which is the high protein and low moisture contents of quinoa milk Rayeb products as compared to control. Dimitreli and Thomareis (2004) concluded that high protein and low moisture contents lead to a high viscosity product. The second factore is the high content of starch in quinoa seeds which ranges from 58.1-64.2% of dry matter (Gordillo-Bastidas et al. 2016). This high level of starch may have influenced the conservation of structure and viscosity. Irreversible changes, such as rupture of hydrogen bonds, water uptake, swelling, melting of crystals or double helices, loss of birefringence, and dissolution, take place during the process of gelatinization, normally accompanied by increased viscosity (Zobel and Stephen 2006). Wang and Zhu (2016) concluded that quinoa flour is used as stabilizing and emulsifying agents because of high protein and starch contents. The third factore behind high viscosity of quinoa milk Rayeb is high WHC of quinoa protein. Codina et al. (2016) reported that since high content of fiber, quinoa flour up to 1.0% addition contributes to an increase in apparent viscosity of yogurt samples, most likely due to quinoa flour's ability to bond water in samples and therefore enhance apparent viscosity. Mabrouk and Effat (2020) found similar results, claiming that adding quinoa flour to bio-yogurt increased viscosity due to the higher starch content while, Tang et al. (2002) mentioned that the increase in apparent viscosity is attributable to the high binding properties of quinoa flour and high starch granules rich in amylopectin used as thickener in frozen and fermented foods. In addition, Filho et al. (2017) mentioned that quinoa flour is good for improving viscosity, stability and water absorption capacity in yogurt. As can be seen from Table 3, the apparent viscosity values of different Rayeb milk treatments gradually decreased during storgae period. This is in close agreement with the report of Lee et al. (2007) who reported that the viscosity of control yogurt and yogurt contained evening primrose oil (EPO) decreased during 15-day storage.

Data of plastic viscosity (or the resistance of fluid to flow) of various Rayeb milk treatments are displayed in Table 3. In contrast to the apparent viscosity results, an increase in amount of quinoa milk was accompanied by a decrease in plastic viscosity of Rayeb milk. The greatest plastic viscosity value was recorded for cow milk Rayeb (T1) while quinoa milk Rayeb had the lowest for fresh samples and through storage stage. During storage, the plastic viscosity of all Rayeb samples reduced.

Yield stress, a rheological property, is characterized as the minimum shear stress needed to initiate flow. It is generally related to the presence of crosslinked or interactive structures (Paoletti et al. 1995) and is additionally linked with the firmness of non-fat yogurt. Addition of quinoa milk caused an increase in yield stress values of Rayeb (Table 3). Quinoa milk at concentrations of 50, 25 and 75% (T3, T4 and T5) increased the yield stress by 6.96, 3.01 and 8.46% for fresh Rayeb samples respectively. Bianchi et al. (2014) demonstrated that in beverages with a higher proportion of quinoa extract, a higher shear stress was required to produce a given strain rate, suggesting that these beverages have stronger structural stability than those with higher levels of soy extract. In the opposite trend, Codina et al. (2016) noticed that shear stress value decreased by increasing quinoa flour level addition from 0.2 to 2.0% as compared with control sample. These findings could be explained by the influence of quinoa flour on casein-particle aggregation, which resulted in gelation, lowering the volume fraction of gel fragments. Because of quinoa flour addition, the gel fragments lost a lot of interstitial solvent, resulting in fewer intermolecular bonds (Walstra et al. 1999). The data of Table 3 revealed that yield srtess of Rayeb milk lowered within storage time. In similar manner, Iličić et al. (2008) found that during 10 days of storage the shear stress of the probiotic yoghurt produced with activation of transglutaminase decreases comparing to measured values of shear stress of the same sample after production. Saleh et al. (2020) showed that yield stress values of yogurt supplemented with various native starches were the highest at seven storage days than zero or 15 days, which could be attributed to maximum physical interaction between the starch and the casein.

Rayeb milk contained quinoa exhibited high levels of consistency coefficient (K) comparing with control treatment. Sample T2 possessed the highest K values during storage period which may be due to the high total solids content consequently the high firmness. According to Amatayakul et al. (2006), the higher the total solid content in the milk, the greater the firmness of the product, hence the higher the consistency index. Karazhiyan et al. (2009) found that the higher value of K indicates a higher firmness of the samples due to enhanced molecular motion restriction caused by entanglements between polymer chains. It is observed from findings of Table 3 that K values of all Rayeb milk treatments lowered during the cold storage stage. Supavititpatana et al. (2010) stated that the consistency values of yogurt made from cow milk or corn milk reduced as storage time increased, but the gel of the cow milk yogurt had lower consistency. A similar trend was observed in the hardness, suggesting that the consistency of the yogurt is related to the strength of the protein-protein interactions of the gel structure.

Table 3 Rheological properties of Rayeb milk made from mixture of cow and quinoa milk

	Treatments	Storage period (day)			
		1	7	14	Means ± SD
Apparent viscosity (mPas)	T1	754.4±4.0	568.3±10.00	410.7±10.0	577.80±14.0^{D}
	T2	949.0±4.0	697.5±14.79	487.0±7.0	709.5±20.6^{A}
	T3	808.2±8.0	611.1±11.00	439.4±1.0	619.57±15.9^{BC}
	T4	773.0±3.0	582.4±2.00	421.1±10	592.17±15.6^{CD}
	T5	899.1±90	649.1±8.30	455.6±5.0	645.7±20.0^{B}
	Means ± SD	837.74±86.30^{a}	606.34±55.0^{b}	442.76±28.60^{c}	
Plastic viscosity (mPas)	T1	107.5±7.0	91.60±5.7	73.10±3.1	91.86±15.78^{A}
	T2	92.5±2.0	72.35±10.0	58.85±10.14	73.9±17.07^{C}
	T3	98.0±10.0	83.95±3.0	64.30±10.06	82.52±15.18^{B}
	T4	101.5±10.0	90.90±5.0	65.55±5.0	85.98±17.12A^{B}
	T5	93.0±3.0	71.95±1.0	57.05±3.5	73.88±15.95^{C}
	Means ± SD	98.5±8.4^{a}	82.82±10.88^{b}	63.58±8.78^{c}	
Yield stress (Pa)	T1	7.33±0.1	5.10±0.1	5.01±1.0	5.81±1.24^{B}
	T2	9.08±0.02	5.84±0.1	5.25±0.1	6.72±1.78^{A}
	T3	7.84±1.0	5.65±1.0	5.07±0.07	6.18±1.44^{AB}
	T4	7.55±0.1	5.08±0.08	4.99±1.0	5.87±1.35^{B}
	T5	7.95±0.1	5.90±0.1	5.01±0.01	6.28±1.30^{AB}
	Means ± SD	7.95±0.73^{a}	5.51±0.53^{b}	5.06±0.55^{c}	
Consistency coefficient (k, mPa s^n)	T1	309.8±6.08	225.9±5.0	203.4±3.0	245.3±47.47^{E}
	T2	476.2±6.0	282.5±20.0	250.4±10.0	336.36±92.42^{A}
	T3	369.3±10.0	239.7±1.0	219.2±10.0	276.06±70.84^{C}
	T4	318.9±4.04	220.4±5.0	205.5±5.0	248.48±53.85^{DE}
	T5	469.3±9.0	254.1±10.0	230.3±5.0	317.9±98.24^{B}
	Means ± SD	388±74.92^{a}	244.52±24.72^{b}	221.76±18.93^{c}	
Flow behavior index (n)	T1	0.37±0.1	0.39±0.01	0.40±0.01	0.38±0.05^{A}
	T2	0.28±0.1	0.32±0.02	0.33±0.03	0.31±0.05^{C}
	T3	0.32±0.02	0.33±0.03	0.35±0.05	0.33±0.03^{BC}
	T4	0.34±0.02	0.36±0.04	0.39±0.03	0.36±0.03^{AB}
	T5	0.29±0.01	0.33±0.01	0.34±0.01	0.32±0.24^{C}
	Means ± SD	0.32±0.06^{b}	0.34±0.03^{ab}	0.36±0.04^{a}	

^{abcd} letters indication to significant differences between the samples of Rayeb ±SD; ^{ABCD} letters indication to significant differences between storage period of Rayeb ±SD; T1: Rayeb from 100% cow milk; T2: Rayeb from 100% quinoa milk; T3: Rayeb from 50% cow milk + 50% quinoa milk; T4: Rayeb from 75% cow milk + 25% quinoa milk; T5: Rayeb from 25% cow milk + 75% quinoa milk

The flow behavior index of Rayeb samples prepared from cow and quinoa milk mixtures is illustrated in Table 3. Generally, fermented milk beverages were found to be non-Newtonian fluids (shear thinning) since $n < 1$. In confirmation of these results, all Rayeb milk treatments manufactured in our study recorded non-Newtonian fluid behavior as n values were well lower than 1. This phenomenon was more pronounced in quinoa Rayeb samples, indicating that they were pseudo-plastic (non-Newtonian) materials. The smaller *n* value indicated a greater departure from Newtonian behavior (Koocheki et al. 2009). At the beginning of storage time, the values of *n* were low and progressively increased during storage. The low levels of *n* showed a more viscous nature of the Rayeb because of its decrease in fluidity.

Conclusion

Consumption of bio-fremented milk products has been increased in recent decades due to its nutritional and health importance. In the present study, bio-Rayeb milk was prepared from cow milk and quinoa milk mixtures with ABT-5 as a starter culture. The addition of quinoa milk enhanced the viability of the probiotic strains during fermentation period. The lightness of Rayeb slightly reduced by fortification with quinoa milk. Rayeb contained quinoa milk exhibited low serum separation, syneresis, plastic viscosity and flow behavior index levels, but high values of apparent viscosity, yield stress and consistency coefficient. According to the findings of this study, it can be concluded that quinoa milk can be mixed with cow milk at 25 and 50% levels in Rayeb milk manufacture. Addition of quinoa milk highly improved the rheological properties of Rayeb milk.

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