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PHYSICOCHEMICAL AND SENSORY CHARACTERISTICS OF KASHK AS INFLUENCED BY QUINOA FLOUR ADDITION

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ABSTRACT

The current work was aimed to study the application of quinoa flour in the production of kashk, a fermented dairy product and the resulting physicochemical and sensory properties. Three kashk samples were formulated with quinoa flour (1,2 and 3)%. Pretreatment of the kashk samples with quinoa flour had significantly increased the viscosity (from 4040 to 4127 cP), acidity value (increased 0.3) and reduced the syneresis of the samples (P < 0.05). Concerning color, no significant changes were observed in the “b” and “L” values in all the samples which remained constant following 60 days of storage whereas an increase in the “a” value was observed upon supplementation of quinoa flour (from -3.00 ± 0.50 to -0.11 ± 0.51). Sensory analysis revealed that increasing the quinoa concentration increased consistency but decreased flavor. Scanning electron micrographs revealed that the denser microstructure was seen in kashk containing quinoa flour. This could suggest that quinoa flour could be used to improve the microstructure of the kashk. Moreover, adding quinoa flour to kashk could compensate lysine depleted in the kashk thermal process. These results indicated that kashk supplementation with quinoa flour could be suggested as an effective means to improve the functional properties of kashk.

Keywords: Quinoa, Viscosity, Kashk, Lysin depletion

INTRODUCTION

Different beneficial effects such as enhanced digestion, tolerance to lactose, antimicrobial properties, hypocholesterolemic, control of blood glucose, antihypertensive consequence, anti-inflammatory, antioxidant action, anti-carcinogenic and anti-allergenic activities have been currently suggested the fermented dairy product (**Kukhtyn *et al*., 2018**).
Kashk is a very old popular fermented Iranian dairy product that is traditionally prepared in dried form and made industrially in a liquid form. The Kashk is a common fermented dairy product in many geographical areas of Iran especially in rural communities (**Golestan *et al*., 2016**). However, similar products have been named in other countries as Tarhana (Turkey and Greece), Kishk (Lebanon and Egypt), Kushuk (Iraq), Madeer-Oggt (Saudi Arabia), Kichk (India), Talkuna (Finland), Tahanya (Hungary) and Atole (Scotland) (Mashak, Sodagari, Mashak, & Niknafs, 2014). Kashk is a product riched in protein and minerals thus, it is considered as one of the important sources of high-quality dairy products recommended using as a dietary supplemented product in the diets of children, pregnant and lactating women (Soltani & Güzeler, 2013). In order to produce the industrial liquid kashk, concentrated yogurt as a byproduct of the industrial dairy companies is mainly used. Few characteristics such as low pH (less than 4.5), 20–25% nonfat solid, 1% fat, 3% salt, and at least 13% protein in the liquid Kashk are currently approved by the Institute of Standard and Industrial Research of Iran) (**Shiroodi *et al*., 2012**). There are only a few studies on the enhancement of kashk texture. For example, rice flour and tragacanth gum were used in kashk as texturizers (**Mashak *et al*., 2014**; **Shiroodi *et al*., 2012**). Additionally, the long-term heat treatment of kashk may cause nutritional value reduction specially lysin. Therefore, it is necessary to add a substance for improving texture and nutritional values.
Quinoa (*Chenopodium quinoa Willd*) is a pseudocereal plant, belongs to the family of Chenopodiaceae and is widely suggested as a beneficial grain. Few unique characteristics such as enriched essential amino acids, lack of gluten, presence of most essential amino acids, lack of gluten and high content and high content of microelements such as Ca, Mg, Fe, flavonoids as important health-promoting compounds, linoleic (52%) and oleic (25%) unsaturated fatty acids make the quinoa seed interesting for consumers. The antioxidant/ antiradical activities of quinoa seed are associated with the presence of tocopherols and carotenoids (**Ruales & Nair, 1993; Ruiz *et al*., 2014; Zhang *et al*., 2014**). Moreover, many validated functional properties of quinoa such as high water holding capacity, gelation and emulsification have allowed its increasing demands (**Graf *et al*., 2015; Valcárcel-Yamani & Lannes, 2012**).
One of the main purposes of adding these ingredients to fermented dairy products is to improve their nutritional values in terms of mineral, vitamins and protein contents (**Zare *et al*., 2011**). However, in the food industry, quinoa flour has been used as thickeners and fat replacers in yogurt (**Codină *et al*., 2016**; **Curti *et al*., 2017**; **Lorusso *et al*., 2018**; **Zannini *et al*., 2018**) cream cheese (**Lemes *et al*., 2016**) beverages (**El-Deeb *et al*., 2014; Ludena Urquizo *et al*., 2017**) and ice-cream (**Jacobsen *et al*., 2003**), although there is no investigations have been conducted on kashk. Consequently, we have supplemented kashk with different concentrations of quinoa flour to see whether any overall acceptability of the product is improved or not.
The objective of our study was kashk supplementation with different concentrations of quinoa flour to see whether any overall acceptability of the product is improved or not.

MATERIALS AND METHODS

Chemicals

The chemicals, solvents and standards include hydrochloric acid, sodium acetate, OPA, ß- mercaptoethanol, sodium hydroxide, sodium acetate, methanol, borate buffer, and the other standard reagents were provided by Merck (Darmstadt**,** Germany). Norovaline was obtained from Sigma Chemicals Co. (**St. Louis**, USA).

Quinoa flour, milk and kashk proximate value

Different factors including moisture, energetic values and macronutrient contents such as fat, ash, proteins and carbohydrates were analyzed in the samples as previously described by AOAC (AOAC, 2016). The following equations were used to evaluate total carbohydrates and energetic values according to (**Cardoso *et al*., 2019**).

Total carbohydrates ($g \cdot 100\ g^{-1}$) =100− (m fat+ m ash+ m proteins) (I);
Energy ($kcal \cdot 100\ g^{-1}$) =4× (m proteins+ m carbohydrates) +[9× (m fat)] (**Ludena Urquizo *et al.*, 2017**).
Few nutrient components including fat, protein, pH, solid nonfat materials, density and freezing point in the fresh milk were analyzed using Cryostar I Funke Gerber 2001 (**Berlin**, Germany) and Lactostar Funke Gerber 2001 (Berlin**,** Germany). The standard test methods for milk and dairy products (Iranian National Standards, 2852 and 10154) were used to report the acidity and microbial counting and Copan kit (Christian Hansen, Hoersholm, Denmark) was employ to determine the antibiotic residues. For kashk analysis, fat, protein, pH and SNF were measured base on the Iranian Standards Institute (NO. 2452). The enumeration of *mold, yeast, Escherichia coli, coliform, Staphylococcus aureus* are currently compulsory in the Kashk samples.

Kashk preparation

In order to prepare the kashk, the standardized milk fat (2.5% w/v) was initially homogenized at 100-200 $kg \cdot cm^{-2}$, pasteurized (at 90 °C for 15 min) and cooled to 43 °C.
Milk was then supplemented with the lyophilized starter culture, CH1 (50U) DVS, followed by incubation at 43 °C to set the acidity at 150° Dornic. The product was then stored at 4–5 °C, overnight. The preparation was then heated to 80 °C for 4 h until its color changed to light brown. The sample was stirred constantly to prevent burning on the interface of the tank. The infrared moisture analyzer MA100 was employed to adjust the total solid to 20% $w \cdot w^{-1}$ (SNF 14.28% $w \cdot w^{-1}$) (Sartorius, Germany) (**Zhang *et al.*, 2014)**. The mixture was finally divided into four equal segments. The supplemented kashk sample consisted of quinoa flour (1, 2, 3) % were added to kashk samples 5 min before homogenization at 75 °C at 100–150 $kg \cdot cm^{-2}$. Control (without quinoa flour) and supplemented product were packed in a hot filling manner at 80 °C in plastic containers and stored at 4 °C. Physicochemical and textural, sensorial properties and apparent viscosity were assessed through the 15 days of storage intervals for 60 days.

pH, total titratable acidity and acid value

The pH of yogurt samples was measured at 1, 15, 30, 45 and 60 days of storage at 4°C using a pH meter (Greisinger electronic, Regenstauf, Germany) with a glass electrode over the range 6.8 to 4.0. The titration of samples with 1/9 $mole \cdot L^{-1}$ NaOH and phenolphthalein was then used to record the dornic acidity.
Acid value was principally defined as the required amounts of potassium hydroxide to neutralize the free fatty acid in each gram of fat. The acid value was determined based on the AOCS: Cd 3a-63 method (**Lemes *et al.*, 2016)**.

Lysin assessment

Lysin was measured in quinoa flour, yogurt, control kashk and the sample containing 3% quinoa. In order to derivate the lysin, the following reagents were used: 0.01 $mol \cdot l^{-1}$ sodium acetate in water (mobile phase A) and methanol (mobile phase B). The borate buffer (0.5 $mol \cdot l^{-1}$; pH: 10.2); for preparation of [2ME; OPA: 2-Mercaptoethanol; O-Phthaldialdehyde] reagent (pH: 9.3): 0.05 gr of the OPA was dissolved in 500μL borate buffer (pH: 9.9) with 4.5 μL methanol and 25 μL of 2-ME, and Norovaline reagent: 50 μL Norovaline (concentration 1000 μM) was added to 950 μL HCl 0.01 $mol \cdot L^{-1}$. The method was performed for lysin analysis including the hydrolysis of quinoa flour samples with 6 $mol \cdot L^{-1}$ HCl and 0.5 $g \cdot L^{-1}$ of β-mercaptoethanol in sealed vacuum-evacuated tubes at 110◦C for 21 h. The outcome precipitate was removed following centrifugation at 6000 g for 30 min. The sample was neutralized using NaOH 3.0 $mole \cdot L^{-1}$. A consecutive sampling of 100 μL of borate buffer and 25 μL of the sample was then mixed twice for 0.5 min. Subsequently, 50 μL of 2ME; OPA reagent was added. 100 μL of HCl 0.1 $mole \cdot L^{-1}$ was taken up and thoroughly mixed six times. After that, 50 μL of this solution was added to 200 μL mobile phase A, mixed twice and 20 μL of the mixture was finally injected. The 10μL of injection volume used for samples. The separation was carried out using a 4 mm x 25 cm with precolumn (PS Spheribond 80-5 ODS 2), AK351, Vertex Plus column, 40 °C, with a flow rate of 1.0 $ml \cdot min^{-1}$ in HPLC system an autosampler system (Perkin Elmer, Australia) equipped with a fluorescence detector (RF-20A series) at λ excitation 348nm and λ emission 450 nm. The reporting of lysin content was made compared to the standard. The retention time for lysin was 4.3 min. The lysin content was expressed in mg· $(kg.\ d.\ m)^{-1}$.

Syneresis calculation

The syneresis (the free whey) was defined by the standard centrifugation method in which, 20g of the sample was centrifuged (640 g, 20min, 4º C), the clear pellet was then collected and weighed. The following equation was finally employed to calculate the syneresis (Eq. 1).

Syneresis =[weight of supernatant (g) /Weight of sample (g)]×100 (Eq. 1)

Sensory assessment

The sensory evaluation including color, taste, texture and overall acceptance based on 5-point hedonic scales (1: dislike extremely; 5: like extremely), was performed by forty trained panelists (aged between 25 to 35 years old). Each sample was scored, individually. The samples were accessible to the panelists in the individual plastic containers. Samples were coded with three digits which were randomly tested by the panel group.

Color

The digital imaging method was applied to evaluate the color using a Chroma meter CR-400, **Konica Minolta, INC** (**Osaka**, Japan). The Chroma meter was calibrated using the white tile. A total of five grams of each sample was placed in a special chamber, the standard color parameters were comprised of brightness (L^* = 23.92), redness (a^* = - 1.29) and yellowness (b^* = 1.19). The average color measurement for each sample was then reported at various sites.

Apparent viscosity

The Brookfield cone and plate viscometer (DV2 Pro II, Brookfield Engineering Laboratories, USA) were used to report the rheological measurement of the samples. The viscometer was equipped with Spindle CP51 and a temperature controller. 0.5 ml of each sample was then transferred into the plate. To achieve a constant solution, the probe was rotated at 50 s^{-1} for 3 min. The device was tuned at 25 ºC for 10 min. The shear rate increased linearly from 1 to 300 s^{-1} for 3 min. . To describe the flow behavior of the kashk mixture, five apparent viscosity equations were used. The best qualities which revealed the highest fitness were finally chosen. The viscosity of the samples was measured at 27 ºC upon 1, 15, 30, 45 and 60th days of storage. For each sample, apparent viscosity records were completed in duplicate. Flow behavior was described by the fitting of the Power law (Eq. 2), Bingham (Eq. 3) and Casson models (Eq. 4)

$$\tau = k\dot{\gamma}^n, \qquad \text{(Eq. 2)}$$

where τ is the shear stress ($D \cdot cm^{-2}$), $\dot{\gamma}$ is the shear rate (s^{-1}), k is the Power law consistency coefficient (cP), and n is the Power law flow behavior index (dimensionless) (Eq. 2).

$$\tau = \tau_{0B} + \eta_B\,\gamma, \qquad \text{(Eq. 3)}$$

where τ_{0B} is the Bingham yield stress ($D \cdot cm^{-2}$) and η_B is the Bingham plastic viscosity (cP) (Eq. 3).

$$(\tau)^{0.5} = k_{0c} + kc(\gamma)^{0.5} \qquad \text{(Eq. 4)}$$

where, k_{0C} and k_C are the intercept and slope of the plot of $(\dot{\gamma})^{0.5}$ versus $(\tau)^{0.5}$, respectively. Therefore, the Casson yield stress ($D \cdot cm^{-2}$) and Casson viscosity (η_C, cP) were calculated as the square of the intercept and slope, respectively [$\tau_{0C} = (k_{0C})^2$, $\eta_C = (k_C)^2$] (Eq. 4).

Texture

The Texture Analyser (TA-XT2, Stable Micro System Ltd., Surrey, UK) was employed to analyze the texture of the samples. A two-bite compression test at pretest speed of 1 mm s^{-1}, test speed of 1 mm s^{-1}, the time interval of 10s and strain deformation of 25% was conducted for the Texture Profile Analysis test. Then, the rest of the sample was tested using a cylindrical probe with a diameter of 80 mm.

Scanning electron microscopy

The freeze-dried samples were fixed on the aluminum holder and covered with gold in a sputter coater (Desk Sputter Coater DSR1, Nanostructural Coating Co., Iran) before an examination on the Scanning Electron Microscopy (SEM, VEGA3, TESCAN, Czech Republic). Samples were then observed under the accelerating voltage of 10.0 kV. The working distance of the microscope lens and sample surface was 7.03- 8.91 mm.

Statistical analysis

Data were analysed by SPSS (ver. 21). For statistical analysis, one-way analysis of variance (ANOVA) was used to analyse the data. The Duncan post-test was used to find the significant difference between the means values ($p < 0.05$).

RESULTS AND DISCUSSION

Quinoa flour, milk and kashk proximate compositions

The physicochemical characteristics of quinoa flour, milk and kashk samples are presented in Table 1. An increase in dry matter and ash content were observed as increasing the quinoa flour concentration.

Table 1 Proximate analysis of quinoa seed flour, Milk and kashk samples

Parameters	Quinoa flour	Milk	Control kashk	1%	2%	3%
pH	4.96+0.02					
Acidity (° Dornic)	9.67+0.33	16				
Dry matter (g·100 g^{-1})	90.30±0.89		26.27+0.06d	27.23+0.55c	28.36+0.45b	30.03+0.45a
Crude proteins (g·100 g^{-1}dw)	16.30±1.52	3.2	5.27±0.12c	7.14±0.04b	7.82±0.64a	7.99±0.10a
Crude fat (ether extract g·100 g^{-1}dw)	6.09±0.30	2.5	7.15±0.09a	6.85±0.11b	6.32±0.05c	5.40±0.20d
Ash (g·100 g^{-1}dw)	4.43±0.47		1.78±0.10d	2.55±0.10c	2.80±0.10b	3.40±0.05a
†Carbohydrates (g·100 g^{-1}dw)	73.14±1.59					
‡Energy (kcal·100 g^{-1} dw)	412.73±0.70					
Density (gr·cm^{-3})		1.035				
Freezing point (°C)		-0.523				
§Antibiotic residue*		Negative				
Total count (CFU·g^{-1})				Absent		

Notes: Values are expressed dw: Dry weight as mean ± SD
† Total carbohydrates =100− (m $_{fat}$+ m $_{ash}$+ m $_{proteins}$)
‡ Energy =4× (% protein + %carbohydrates) + 9× (% fat)
§Antibiotic residue is affecting the fermentation rate. Antibiotic residue detection was carried out according to Iranian national standard (NO. 13559).
Mold, yeast, *E. coli*, *coliform*, *staph aureus* which included Iranian compulsory standards of kashk (NO. 2452) did not exist in produced kashk.

pH, titratable acidity and acid value

Prominent alterations in the pH and acidity values were recorded the following incubation at 4°C for 60 days of storage (Figures 1 and 2). Samples treated with greater concentrations (3%) of quinoa flour revealed a higher increase in the total acidity values in comparison to control kashk, until 30 days of storage time. One of the reasons might be that residual lactose consumption and acid production in supplemented kashk were faster than control. A considerable reduction in the pH values of quinoa flour supplemented products was observed as similar to the control (**Casarotti *et al.*, 2014; Curti *et al.*, 2017)**. As such, a considerable reduction in the shelf life of samples had resulted from the addition of quinoa flour which could potentially influence the following acceptability of products.
High significant differences were found between the acid degree value of the kashk containing 3% quinoa and control (Table 2). One reason for the high acid value is lipolysis. An increase in the lipid oxidation was occurred due to the activation of lipolytic enzymes caused mainly by the addition of ground quinoa to the subsequent keeping in the quality of the product (**Ng *et al.*, 2007)**. Furthermore, the fermentation process, the production of short-chain fatty acids (lactic, acetic) and water contribute to an increase in the acid value of the fat (**Turek *et al.*, 2018)**.

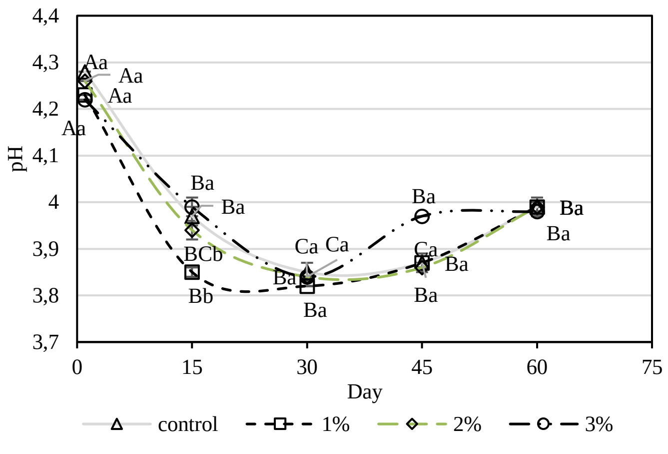


Figure 1 pH of kashk samples during storage time. 1- Data (mean ± standard deviation) are from three replications. 2- Different lowercase letters in each line represents significant differences during the time(p≤0.05). 3-Different capital letters indicate significant differences among kashk samples at the same time (0, 15, 30, 45 and 60 days) separately (p≤0.05).

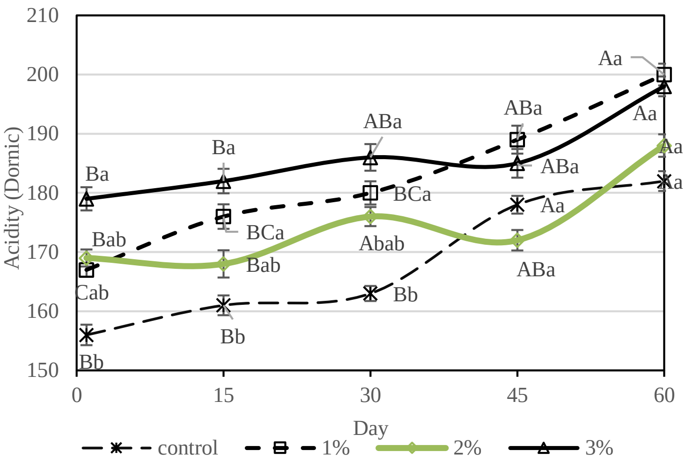


Figure 2 Acidity of kashk samples during storage time. 1- Data (mean ± standard deviation) are from three replications. 2- Different lowercase letters in each line represents significant differences during the time(p≤0.05).3-Different capital letters indicate significant differences among kashk samples at the same time (0, 15, 30, 45 and 60 day) separately (p≤0.05).

Syneresis measurement

The kashk supplemented with quinoa flour had presented a lower significant syneresis (P < 0.05) than the control, as shown in Table 2. The ability of quinoa flour to bind water, interact with the milk components especially proteins and preventing the free movement of water are among the different functions of the quinoa in the dairy gel or gel-like systems(**Shiroodi *et al.*, 2012)**. The result of increasing the overall dense content, especially the protein component, revealed the stronger texture and the less whey separation in the supplemented kashk (**Peng *et al.*, 2009)**. This can explain the lowest syneresis in 3% quinoa flour supplemented kashk. Similar findings were previously reported **by Zare et al, (2011)**, they showed that lentil flour supplementation (3%) in yogurt resulted in lower syneresis in comparison to control during the 28 days storage.

Sensory evaluation

The sensory scores of the kashk samples are given in Figure 3. The points allocated for the color, consistency, odor, taste and total acceptance showed that an increase in quinoa flour content brought about an improvement in the consistency of the products (p≤ 0.05) although diminishing the taste. The addition of quinoa flour did not affect the odor and color properties of kashk samples (p> 0.05). Kashk containing 2% quinoa was found to be particularly noticeable in total acceptance. One reason to explain this acceptability could result from the homogeneity of curd which made the gelly appearance of kashk (**Loveday *et al.*, 2013)**.

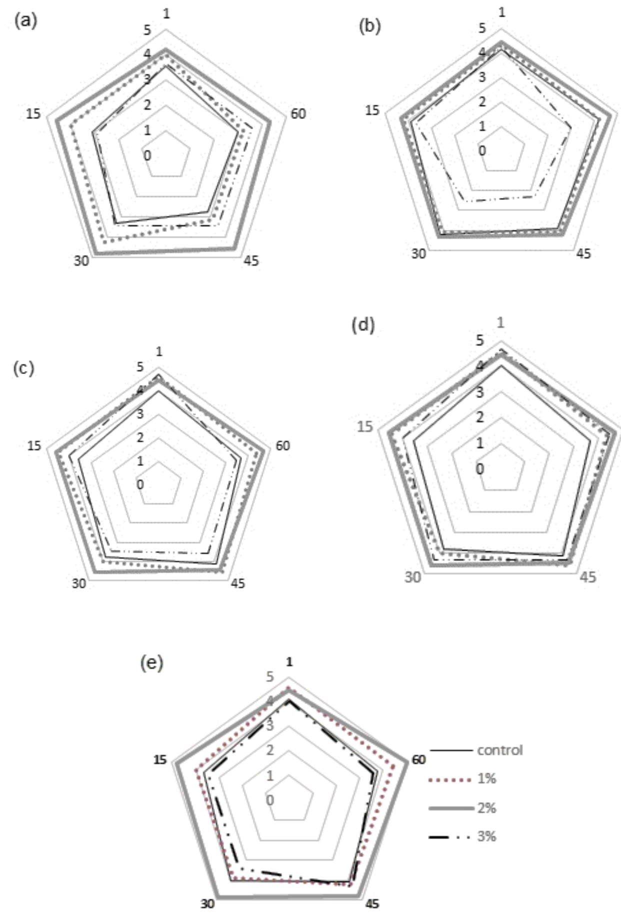


Figure 3 Sensory attributes of kashk samples supplemented with quinoa flour. Odor **(a)**; Taste **(b)**; colour **(c)**; consistency **(d)** total acceptance **(e).**

Color

Table 2 Illustrates the color parameters in different kashk during the storage period. Concerning L* and b* parameters, no considerable change was observed in the following supplementation of the samples with quinoa flour. The quinoa flour did not alter the light scattering properties of the sample and thus no differences in the lightness of the samples were observed .When assessing the a* parameter, kashk containing three percent quinoa flour presented a value closer to 0 demonstrating higher proximity to red, which is significantly different (p≤0.05) from the control sample. A similar result was seen in yogurt supplemented with three percent of lentil flour which revealed a reddish appearance to some extent (**Zare *et al.*, 2011)**.

Table 1 Free fatty acid, syneresis and color parameters of kashk samples during storage time.

†T	Day	Control	1%	2%	3%
ADV	1	0.60±0.01^{Da}	0.40±0.04^{Cb}	0.70±0.04^{Ca}	0.60±0.01^{Ca}
	15	0.90±0.02^{Ca}	0.80±0.03^{Bc}	0.90±0.04^{Bbc}	1.00±0.04^{Bb}
	30	1.00±0.03^{Ba}	1.10±0.05^{Aa}	1.00±0.01^{ABa}	1.10±0.04^{Ba}
	45	1.10±0.01^{Aab}	1.00±0.03^{Ab}	1.10±0.03^{Aab}	1.30±0.04^{Aa}
	60	1.10±0.02^{Ab}	1.00±0.03^{Ab}	1.00±0.04^{ABb}	1.40±0.04^{Aa}
Syneresis	1	2.00±0.05^{Aa}	1.00±0.11^{Ab}	0.50±0.05^{Ac}	.00±0.00^{Ad}
	15	1.50±0.11^{Ba}	1.00±0.11^{Ab}	0.50±0.05^{Ac}	0.00±0.00^{Ad}
	30	1.00±0.05^{Ca}	0.80±0.11^{Aa}	0.50±0.05^{Ab}	0.00±0.00^{Ad}
	45	1.00±0.11^{Ca}	0.70±0.05^{Ab}	0.30±0.11^{Ac}	0.00±0.00^{Ad}
	60	1.10±0.11^{Ca}	0.60±0.02^{Bb}	0.50±0.11^{Ab}	0.00±0.00^{Ad}
L*		70.11±3.56^{Aa}	69.88±3.99^{Aa}	66.00±3.02^{Aa}	67.66±2.77^{Aa}
a*	1	-3.22±0.46^{ABb}	-3.11±0.75^{Bb}	-0.11±0.69^{Aa}	-0.66±0.72^{Aa}
b*		14.00±1.09^{Bb}	17.33±0.66^{Aa}	15.33±0.83^{Ba}	17.66±1.67^{Aa}
L*		61.66±2.04^{Aa}	65.88±3.04^{Aa}	70.33±3.60^{Aa}	68.55±3.14^{Aa}
a*	15	-0.55±0.50^{Aab}	-1.22±0.77^{Bb}	0.88±0.38^{Aa}	0.44±0.64A^{Ba} b
b*		17.88±0.45^{Aa}	18.00±0.50^{Aa}	17.55±0.62^{Aa}	17.00±0.76^{Aa}
L*		60.88±4.99^{Aa}	59.66±3.75^{Ba}	63.77±3.00^{Aa}	57.88±3.84^{Ba}
a*	30	-0.33±0.33^{Aa}	-0.44±0.41^{Aa}	0.44±0.24^{Aa}	-0.11±0.26^{Aa}
b*		14.44±1.34^{ABb}	18.22±0.68^{Aa}	18.33±1.08^{Aa}	18.00±0.94^{Aa}
L*		63.22±3.40^{Aa}	64.11±1.82^{ABa}	62.44±2.61^{Aa}	65.66±3.04^{Aba}
a*	45	-2.00±0.44^{Ba}	-0.66±0.64^{Aa}	-0.66±0.33^{Aa}	-0.55±0.58^{Aa}
b*		15.55±0.62^{ABa}	17.66±0.40^{Aa}	17.55±0.68^{ABa}	17.22±0.95^{Aa}
L*		65.11±2.63^{Aa}	57.11±2.81^{Ba}	63.33±5.09^{Aa}	62.88±5.09^{Aba}
a*	60	-3.00±0.50^{ABb}	0.11±0.65^{Aa}	-0.33±0.66^{Aa}	-0.11±0.51^{Aa}
b*		17.33±1.57^{ABa}	17.11±0.45^{Aa}	16.77±0.72^{ABa}	15.33±0.72^{Aa}

Notes: †L* ranges from 0 (black) to 100 (white), a* ranges from red (+ a*) to green (-a *) and b* ranges from yellow (+ b *) to blue (-b *);
‡ Different capital letters in the column (A-C) differ significantly (P≤0.05); different letters(a-c) in the row differ significantly (P≤0.05).

Lysin assessment

The Maillard (nonenzymatic glycation) is described as a complicated chemical reaction that may occur between the amino and the carbonyl groups which gives a browned appearance to some foodstuffs. This reaction usually develops during food processing and/or storage. Generally, in the Maillard reaction, lactose essentially reacts with the Gamma-amino group of residual lysine that exists in milk proteins. Thus, the degree of the disappearance of lysine is correlated with the severity of heat treatment (**Shimamura & Ukeda**, **2012)**. In this study, the lysin content in quinoa flour, yogurt without any heat treatment, control kashk and kashk containing 3% quinoa were 308.29, 80.23, 55.33, 89.07 ppm separately (Figure 4). Thus, adding quinoa flour to kashk can compensate lysine lost in the kashk thermal process.

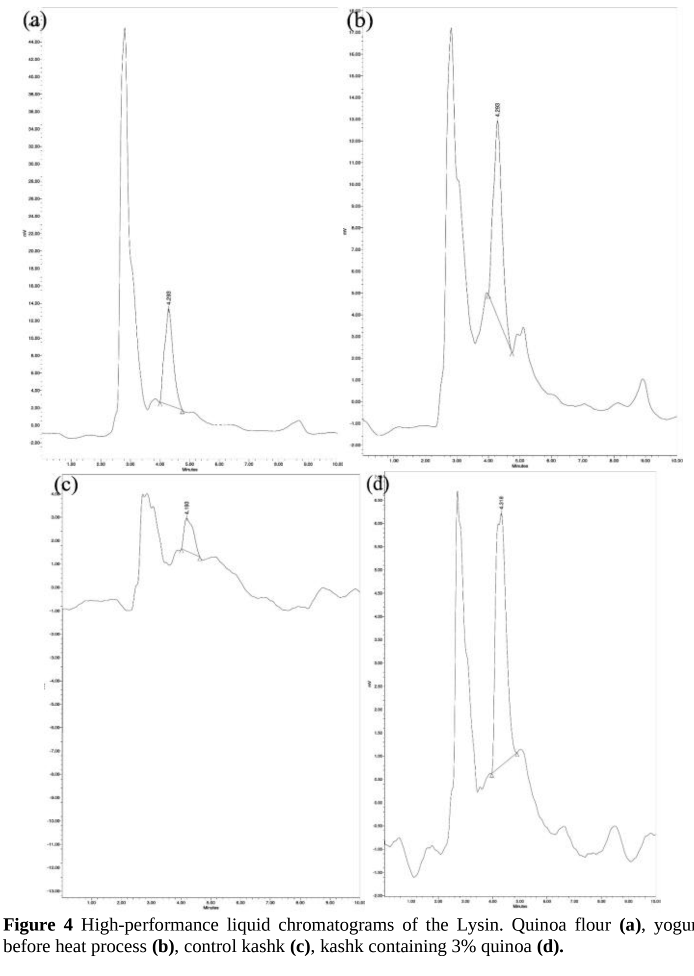


Figure 4 High-performance liquid chromatograms of the Lysin. Quinoa flour **(a)**, yogurt before heat process **(b)**, control kashk **(c)**, kashk containing 3% quinoa **(d).**

Apparent Viscosity

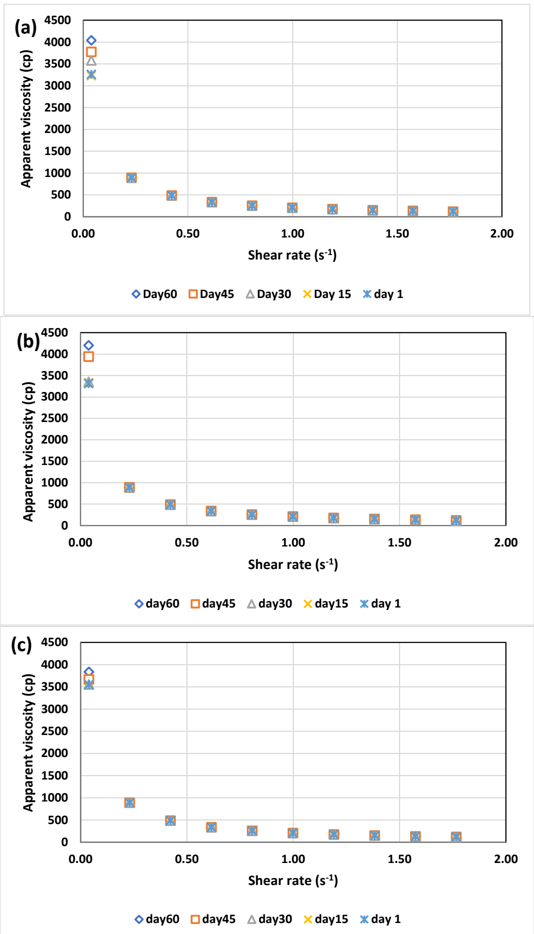
The apparent viscosity of quinoa supplemented kashk samples is presented in Table 3. The power law, Bingham and Casson models were found appropriate in this study to express the following behavior of kashk samples. The non-Newtonian behavior occurred in the following manner a reduction in the apparent viscosity of the kashk samples with increasing shear rate (Figure 5). Following a rapid reduction, the apparent viscosity changed slightly and became stable at higher shear rates. This could be due to the decrease in particle size as the consequence of increasing the shear rate (**Sekhavatizadeh *et al.*, 2019)**. The viscosity increased during the storage time among all samples. It is worth mentioning that post acidification caused the deterioration of the negative electric charge of the casein micelles resulted from dissolving the calcium and inorganic phosphate which attenuates colloidal stability and subsequently the casein becomes insoluble near its isoelectric pH (about 4.6). This phenomenon, strengthening of protein-protein complexes leads to enhance viscosity (**Dönmez *et al.*, 2017**). For the power law, Bingham and Casson models, the determination coefficient (R^2) values were nearly 0.95, 0.93, 0.96 which showed the appropriate findings for these models (Table 3). As can be viewed, no significant differences were found in the flow index values between all samples at the initial and end of the storage ($p > 0.05$). In general, the lower flow index (n) values (<1) and higher consistency coefficient cause the occurrence of pseudo-plastic (non-Newtonian) materials at every concentration of quinoa flour (**Yang *et al.*, 2012**).

Yield stress is suggested as a significant quality control value in the industrial procedures, typically for matching the comprehensive features of products made on different production sites (**Haminiuk *et al.*, 2006**).

The shear rate ranged between 3.84 to 176.64 (s^{-1}) as resulted from the influence of quinoa flour proportions on shear stress (cP) of kashk (151.33 to 127.22 cP). A decrease in the level of shear stress values was denoted a clear decline in the shear stress value after increase the concentration of quinoa flour from 1 to 3%. These findings could result from the gelation of quinoa flour which formed from the aggregation of casein-particle. Fewer intermolecular bonds formed, due to the lack of enough interstitial solvents, after the addition of quinoa to the samples (**Codină *et al.*, 2016**).

In the power-law equation, the results showed that the control kashk and the sample containing 3% quinoa flour had the highest consistency coefficient. But 1% quinoa flour sample had the lowest, on the first day of storage. While at the end of the storage, the kashk sample contained 3% quinoa flour and the control had the highest; the lowest flow index was at 15681 and 13601 (cP), respectively. The higher value of k indicates that a higher firmness of the samples that occur after limiting molecular movement had increased as a result of the interaction between polymer chains (**Karazhiyan *et al.*, 2009**).

The results (Casson and Bingham models) showed that a high level of supplemented quinoa flour (3%) had a lower plastic viscosity in the samples upon 60 days of the storage time. An increase in the viscosity of samples was observed following the addition of up to 1.0% of quinoa flour. This was likely associated with the increase in bond water in the samples. This is beneficial as the product may keep its stability for a longer period (**Codină *et al.*, 2016**).



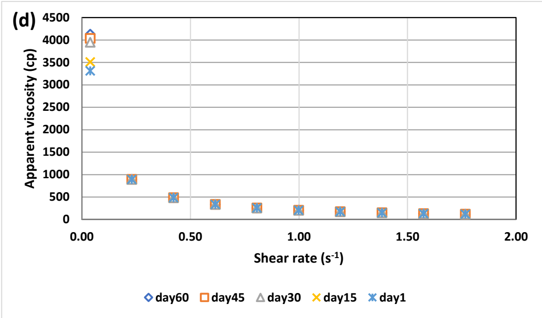


Figure 5 The apparent viscosity of the kashk samples containing different quinoa flour during storage. Control **(a)**; 1% quinoa flour **(b)**; 2% quinoa flour **(c)**; 3% quinoa flour **(d)**.

Table 3 Viscosity parameters of kashk fortified with quinoa

Viscosity parameter		Day	Control	1%	2%	3%
Bingham	η_B (cP)	1	14.14±5.25Aa	21.55±0.35Aa	19.50±1.90Aa	14.20±3.70Ba
		15	20.20±2.80Aa	20.65±0.35Aa	19.50±0.10Aa	20.00±0.90ABa
		30	17.00±3.40Aa	19.60±0.30Aa	17.30±1.10Aa	15.80±0.60ABa
		45	22.65±0.55Aa	15.22±6.17Aa	16.35±1.55Aa	22.10±1.10Ba
		60	18.05±0.15Aa	12.37±4.43Aa	18.25±3.05Aa	13.20±1.10Ba
	τ_{0B} (D·cm^{-2})	1	187.20±6.60Aa	177.80±0.20Aa	180.60±2.40Aa	187.20±4.70Aa
		15	179.65±3.55Aa	179.10±0.50Aa	180.55±0.15Aa	179.95±1.15ABa
		30	183.65±4.25Aa	180.45±0.35Aa	183.35±1.35Aa	185.15±0.75ABa
		45	176.50±0.70Aa	185.85±7.75Aa	184.50±1.90Aa	177.25±1.35Ba
		60	180.95±1.25Aa	189.45±5.55Aa	182.10±3.80Aa	188.45±1.35Aa
	R^2	1	94.85±2.15Aa	91.65±0.05Aa	92.65±0.85Aa	94.90±1.50Aa
		15	92.30±1.30Aa	92.15±0.15Aa	92.65±0.05Aa	92.45±0.45ABa
		30	93.75±1.45Aa	92.65±0.15Aa	93.65±0.45Aa	94.30±0.30ABa
		45	91.15±0.25Aa	94.35±2.55Aa	94.05±0.65Aa	91.45±0.55Ba
		60	92.50±0.80Aa	95.60±1.70Aa	93.20±1.40Aa	95.35±0.45Aa
Casson	η_C (cP)	1	1.40±0.96Aa	3.03±0.06Aa	2.42±0.52Aa	1.31±0.68BCa
		15	2.67±0.81Aa	2.72±0.11Aa	2.39±0.03Aa	2.52±0.25ABa
		30	1.87±0.78Aa	2.41±0.07Aa	1.84±0.25Aa	1.50±0.12BCa
		45	3.36±0.19Aa	1.71±1.25Aa	1.64±0.33Aa	3.18±0.35Aa
		60	2.10±0.06Aa	1.04±0.69Aa	2.14±0.76Aa	1.03±0.18Ca
	YS(D·cm^{-2})	1	173.20±12.10Aa	155.75±0.45Aa	160.90±4.50Aa	173.20±8.60Aa
		15	159.15±6.65Aa	158.20±0.90Aa	160.90±0.30Aa	159.80±2.10ABa
		30	166.65±7.95Aa	160.70±0.60Aa	166.10±2.50Aa	169.55±1.45ABa
		45	153.30±1.30Aa	170.65±14.35Aa	168.25±3.55Aa	154.70±2.60Ba
		60	162.80±2.30Aa	177.35±10.15Aa	163.85±7.15Aa	175.50±2.50Aa
	R^2	1	97.60±1.00Aa	96.15±0.05Aa	96.60±0.70Aa	97.60±0.70Aa
		15	96.45±0.55Aa	96.40±0.10Aa	96.60±0.00Aa	96.50±0.20ABa
		30	97.10±0.70Aa	96.60±0.10Aa	97.05±0.25Aa	97.35±0.15ABa
		45	95.95±0.15Aa	97.40±1.20Aa	97.20±0.30Aa	96.05±0.25Ba
		60	96.85±0.05Aa	98.00±0.80Aa	96.85±0.65Aa	97.80±0.20Aa
Power law	K_p(cP)	1	15339.50±1909.50Aa	12620.00±67.00Aa	13412.00±687.00Aa	5318.00±1353.00Aa
		15	13146.00±1011.00Aa	12991.50±133.50Aa	13401.50±47.50Aa	3239.50±324.50ABa
		30	14302.50±1234.00Aa	13373.50±95.50Aa	14204.50±392.50Aa	4740.50±220.50ABa
		45	12258.50±199.50Aa	14948.50±2242.50Aa	14539.50±555.50Aa	12468.00±390.00Ba
		60	13601.00±288.00Aa	15982.00±1615.00Aa	13862.00±1099.00Aa	15681.00±394.00Aa
	n	1	0.065±0.025Aa	0.110±0.000Aa	0.090±0.010Aa	0.065±0.015BCa
		15	0.095±0.015Aa	0.100±0.000Aa	0.090±0.000Aa	0.095±0.005ABa
		30	0.080±0.020Aa	0.095±0.005Aa	0.080±0.010Aa	0.075±0.005BCa
		45	0.115±0.005Aa	0.070±0.030Aa	0.075±0.005Aa	0.110±0.10Aa
		60	0.090±0.000Aa	0.055±0.025Aa	0.085±0.015Aa	0.055±0.005Ca
	R^2	1	96.20±1.55Aa	93.95±0.05Aa	94.65±0.65Aa	96.30±1.10Aa
		15	94.40±1.00Aa	94.30±0.10Aa	94.65±0.05Aa	94.50±0.30ABa
		30	95.45±1.05Aa	94.65±0.05Aa	95.35±0.35Aa	95.85±0.15ABa
		45	93.60±0.20Aa	95.90±1.90Aa	95.70±0.50Aa	93.80±0.40Ba
		60	94.30±0.80Aa	96.80±1.30Aa	95.05±0.95Aa	96.60±0.30Aa

Notes: †Yield stress; ‡ plastic viscosity
k_P: the Power law consistency coefficient, n_P: the Power law flow behavior index, η_B: the Bingham plastic viscosity, τ_{0B}: the Bingham yield stress (D·cm^{-2}), η_C: Casson viscosity (cP), YS: Casson yield stress (D·cm^{-2}),
Different capital letters in the column (A-D) differ significantly (P≤0.05); different letters (a-c) in the row differ significantly (P≤0.05).

Texture

The texture of kashk samples are shown in Table 4 indicated the fortifying kashk with 3.0% quinoa flour had a significant effect on the textural properties. Hardness and gumminess increased and adhesiveness, chewiness, springiness and cohesiveness decreased significantly. The binding of proteins could lead to a rise in the firmness of samples during storage. However, the lowest values of hardness were occurred by the end of the storage (on day 60). The samples enriched with 3% of quinoa flour revealed the highest value of firmness (**Hosseini & Ansari, 2019)**. An increase in the hardness of whole skimmed flavored yogurt after a long storage time was reported (**Salvador & Fiszman, 2004)**. The increase in the hardness of different varieties of kashk samples observed in our study on account of the addition of quinoa flour may be associated with the increase in the dry matter content (Table 1). The presence of amylase/ amylopectin in the starch chain which contributed to the reactive groups in the quinoa flour may produce its emulsifying property which finally tended to a higher level of water absorption, the greater viscosity in the continuous phase and firmer texture in the treated kashk (**Hosseini & Ansari, 2019)**. Moreover, hardness might be related to quinoa flour absorbing more moisture because of its higher water-holding capacity.

The highest values of hardness are associated with a greater reorganization of proteins in the gel network. Cohesiveness is described by a large number of broken casein-casein connections during the stress circumstances together with springiness (the ability to recover its initial condition after applying a deformation) (**Curti *et al.*, 2017)**. The Adhesion was significantly decreased during the storage. It is supposed that the long refrigerating storage of kashk samples made amylose more likely to bind casein micelles in quinoa flour, and thus a stronger three-dimensional network was formed with more stiffness which caused reducing the process of adhesion. This result was supported by (**Hosseini & Ansari, 2019)** regarding three forms of modified tapioca starch which were incorporated into industrial liquid kashk. The result of their study revealed a significant decrease in the adhesiveness and a simultaneous increase in the hardness of samples ($p \leq 0.05$). An adverse relationship between adhesiveness and hardness was therefore reported.

Table 4 Texture parameters of kashk fortified with quinoa

†T	Day	Control	1%	2%	3%
Hardness	1	0.065±0.001Dd	0.215±0.03Ac	0.356±0.03Bb	0.721±0.03Ba
	15	0.125±0.001Cd	0.213±0.001Ac	0.367±0.001Bb	0.814±0.00Ba
	30	0.141±0.001BCd	0.291±0.01Ac	0.384±0.02Bb	0.871±0.01Ba
	45	0.157±0.001Bb	0.605±0.31Aab	0.579±0.001Aab	1.051±0.02Aa
	60	0.200±0.01Ac	0.325±0.01Ac	0.577±0.01Ab	1.114±0.08Aa
Adhesiveness	1	0.096±0.001Ba	0.188±0.001Ab	0.568±0.01Bc	0.200±0.02Ab
	15	0.165±0.001Ba	0.375±0.05ABb	0.582±0.02Bc	0.350±0.05Ab
	30	0.178±0.001Ba	0.448±0.01Bb	0.305±0.02Ac	0.550±0.05Ac
	45	0.108±0.001Aa	0.532±0.02Bb	0.575±0.02Bb	0.617±0.10Ab
	60	0.384±0.02Ca	0.308±0.13ABa	0.721±0.11Ba	0.417±0.30Aa
Chewiness	1	0.48±0.001Dc	0.131±0.001Ab	0.206±0.01Ba	0.153±0.02Cb
	15	0.065±0.001CDc	0.135±0.03Abc	0.225±0.001Bab	0.247±0.03Ba
	30	0.079±0.001Cb	0.154±0.001Aab	0.175±0.04Ba	0.141±0.00Cab
	45	0.108±0.00Bd	0.184±0.001Ac	0.161±0.001Bb	0.320±0.00ABa
	60	0.145±0.001Ab	0.133±0.04Ab	0.347±0.001Aa	0.344±0.02Aa
Cohesiveness	1	0.818±0.001Aa	0.663±0.08Aa	0.634±0.01Aa	0.322±0.03ABb
	15	0.675±0.02Aa	0.687±0.15Aa	0.656±0.03Aa	0.437±0.05Aa
	30	0.636±0.08Aa	0.592±0.04Aa	0.536±0.02Aa	0.276±0.00Bb
†T	Day	Control	1%	2%	3%
Cohesiveness	45	0.745±0.05Aa	0.713±0.05Aa	0.330±0.02Bb	0.340±0.02ABb
	60	0.799±0.001Aa	0.458±0.07Ab	0.667±0.05Aa	0.399±0.03ABb
Gumminess	1	0.052±0.001Dc	0.139±0.001Ab	0.225±0.01Ba	0.231±0.01Ba
	15	0.083±0.001Cc	0.146±0.03Abc	0.240±0.01Bb	0.356±0.04ABa
	30	0.089±0.001Cc	0.171±0.001Ab	0.206±0.02Bab	0.236±0.02ABa
	45	0.116±0.001Bc	0.201±0.001Ab	0.191±0.01Bb	0.356±0.02ABa
	60	0.159±0.001Ac	0.150±0.03Ac	0.862±0.001Aa	0.446±0.06Ab
Springiness	1	0.936±0.001Aa	0.945±0.01Aa	0.917±0.01Aa	0.678±0.14ABa
	15	0.918±0.001ABa	0.926±0.01Aa	0.938±0.01Aa	0.693±0.00ABb
	30	0.896±0.02Ba	0.903±0.02Aa	0.840±0.10Aa	0.598±0.03Bb
	45	0.933±0.001ABa	0.918±0.001Aa	0.850±0.05Aa	0.905±0.06Aa
	60	0.913±0.001ABa	0.870±0.09Aa	0.862±0.001Aa	0.780±0.06ABa

Different capital letters in the column (A-D) differ significantly ($P \leq 0.05$); different letters (a-c) in the row differ significantly ($P \leq 0.05$). The texture parameter consist of Hardness (kg), Adhesiveness ($kg \cdot s^{-1}$), Chewiness ($kg \cdot s^{-1}$), Cohesiveness, Gumminess (kg), Springiness (mm). †Texture parameters

Scanning electron microscopy

Details of the scanning electron micrograph of kashk samples supplemented with various concentrations of quinoa flour are given in Figure 6. A relatively denser appearance was revealed in the protein matrices of the supplemented samples that resulted in improved gel strength and lessen syneresis. This was confirmed by the textural, sensory and syneresis data (Tables 4, 2 and Figure 3). The micrograph displayed the highest strength of 3% quinoa flour supplemented kashk gels from cross-linked, which is due to a well-organized protein network with smaller pores in the product (**Farnsworth *et al.*, 2006)**. The control kashk sample network had the most pores or void spaces in which the aqueous phase was retained (**Lee & Lucey, 2010)**.

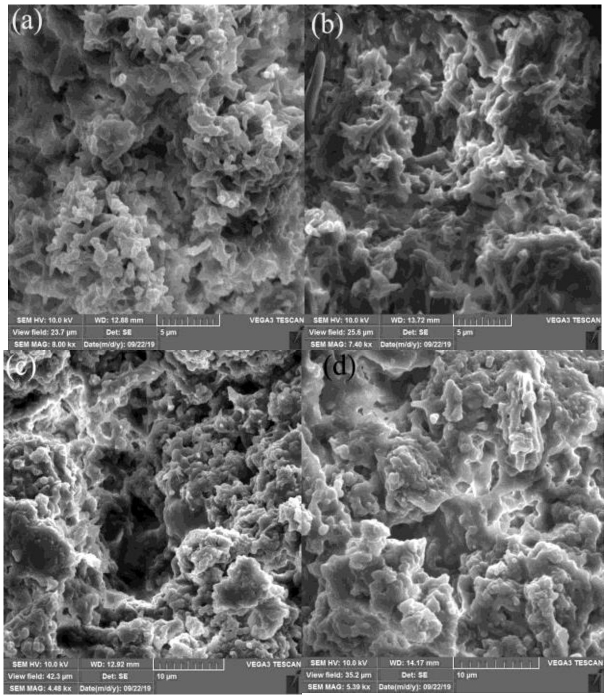


Figure 6 Scan electron microscopy images of kashk samples. Control **(a)**; 1% quinoa **(b)**; 2% quinoa **(c)**; 3% quinoa **(d)**.

CONCLUSIONS

In the present study, overall acceptability and lower syneresis of the quinoa-supplemented product were observed. The addition of quinoa flour in yogurt intensified the consistency although the flavor was higher in kashk. The addition of quinoa flour had not altered the odor and color properties of kashk samples. SEM micrographs demonstrated that 3% of quinoa flour could be used in kashk to improve the gel microstructure. Moreover, reducing lysine in the kashk heat process is compensated by the addition of quinoa flour. The results of this study promisingly provide opportunities to apply quinoa flour in food industries. Future research can investigate the possible function of quinoa flour on other dairy products. Specifically, the potential for sample profitableness of different variants of kashk supplemented with quinoa flour can also be investigated.

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