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RESEARCH ARTICLE

RIPENING OF SUDANESE BRAIDED (MUDDAFFARA) CHEESE MANUFACTURED FROM RAW OR PASTEURIZED MILK: EFFECT OF HEAT TREATMENT AND SALT CONCENTRATION ON MINERAL CONTENT

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Abstract

The aim of the study was to investigate the effect of heat treatment and salt concentration (0%, 5%, and 10%) on the mineral profile of Sudanese braided cheese (SBC) ripened for up to 3 months at 5±2°C. Both heat and salt treatments significantly ($P < 0.05$) affected the mineral profile of SBC. Braided cheese (BC) manufactured from pasteurized milk (BCPM) always had higher mineral contents ($P < 0.05$) than BC manufactured from raw milk (BCRM) except for Co. BCPM was superior to BCRM in the contents of Cu, K and Zn by 757%, 200% and 125% respectively. Mineral content of BC responded differently to salt concentrations (SC). Some minerals (Ca, Na, Mg, Cu and K) contents increased ($P < 0.05$) with the increase in SC showing overall changes that ranged between 21% and 295%. The rest of minerals tested (P, Zn, Fe and Co) decreased by 3% to 58% with the increase in SC. The Na and Fe contents of BC increased ($P < 0.05$) as storage periods progressed. Calcium did not show any change in content up to 60 days of storage thereafter at 90 days its content increased significantly ($P < 0.05$). Generally the three factors tested exhibited significant interactions on the minerals contents of the BC. With or without heat treatment, the concentrations of Cu, Na, and K increased ($P < 0.05$) with the increase in salt concentration. This piece of work revealed the effects of different processing conditions on the potentiality of SBC as a good source of some minerals important for consumer health.

Key words: Braided Cheese, Minerals, Pasteurization, Salt concentration, Interactive effects.

Introduction

In fact, milk and its related products have long been key foods, which contributed to food security in many African countries to a point that they were considered holy by many people in rural communities. Due to the highly perishable character of milk, there has been a need to develop appropriate methods to allow its conservation for longer periods (Abd-El Salam and Benkerroum, 2006; Mohamed Ahmed *et al*., 2010). Thus, milk is processed into different products such as butter, cheese, dried milks, ice

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cream, and condensed milk. Milk, cheese, and yogurt provide the many beneficial nutrients in varying quantities (The Dairy Council, 2009). Cheese provides a high concentration of nutrients relative to its energy content. The nutritional composition of cheese depends on the type of milk used and the manufacturing and ripening procedures (Walstra *et al*., 2006). The mineral compounds participate in the coagulation influence the draining of the whey and the texture of the curd and on properties such as stability to heat and the capacity of coagulation (Patiño *et al*., 2005). Particularly, during cheese ripening some of the mineral salts may migrate from the central part towards the external layer of the cheese block or vice versa (Gambelli *et al*., 1999). The consumption of cheese is of great nutritional interest, due in particular to its composition of micronutrients and especially minerals (Lucas *et al*., 2008). The heavy metal content of cheese is variable due to factors such as differences between species, geographical area, characteristics of the manufacturing practices and possible contamination from the equipment during the process (Mendil, 2006). Gonzalez-Martin *et al*. (2009) reported that ripening had significant effects on the concentrations of all the studied minerals with the exception of Zn, a phenomenon which could be due to different degrees of mobility of different elements.

Cheese making in Sudan is the major preservation method for milk surplus in rural areas especially during the rainy season when plenty of milk is available (El Owni and Hamid, 2008). One typical cheese variety now being produced in Sudan is braided cheese (locally known as Muddaffara). Braided cheese is becoming a popular cheese in Sudan and other Middle Eastern countries. It is a semi hard cheese with hard texture, yellowish color and slightly acid and salt taste (El-Sheikh, 1997). About 7500 tons of braided cheese is manufactured in Sudan annually is sold in the local markets (FAO, 2005). However, research dealing with the minerals content of Sudanese braided cheese made from raw cow milk is scarce. Moreover, there is no study on the Sudanese braided cheese as affected by use of pasteurized cow milk and different salt levels on mineral profile during ripening. Therefore, the aim of this study was to investigate the effect of heat and salt concentration on minerals content of Sudanese braided cheese during storage periods.

Materials and methods

Materials

Fresh cow's milk was obtained from Khartoum University Farm. Rennet, (Chr. Hansen's, Denmark), $CaCl_2$ was a product of Sigma Chemical Company, NaCl and Black cumin (*Nigella sativa*) were obtained from the local market. All chemicals and reagents used were of technically recommended analytical grade.

Cheese Manufacture

The general protocol used by several investigators for braided cheese manufacture was followed with few modifications (Fig 1). Briefly, the obtained fresh cow milk (10 kg) was divided in two equal portions. One was used as raw milk and warmed to 40°C without pasteurization and the other was pasteurized at 72°C for 15 seconds and allowed to cool to 40°C. Then starter culture with a combination of 1:1 *lactobacillus bulgaricus* and *streptococcus thermophilus* (0.02 %), rennet (1tablet / 50kg milk) and $CaCl_2$ were added to both milks. After complete coagulation (about 45 min), the curd was cut or broken to small parts and incubated until the required acidity (0.49-0.67 lactic acid %) for kneading was reached. The curd was put on a wooden table, and left for (5 min) to drain off the remaining whey. The curd was then cooked in 500 mL of whey at 70-80°C for five minutes. A natural flavoring ingredient such as black cumin was added (0.5%) to the hot paste, then cut into small pieces and flattened-like a circle shape. The curds formed where then braided, divided into three equal portions, each packed in plastic container assigned randomly to one of the three salted whey (0%, 5%, and 10% salt) in a ratio of 1:1 (cheese: whey) and stored for up to 90 days at 5±2°C.

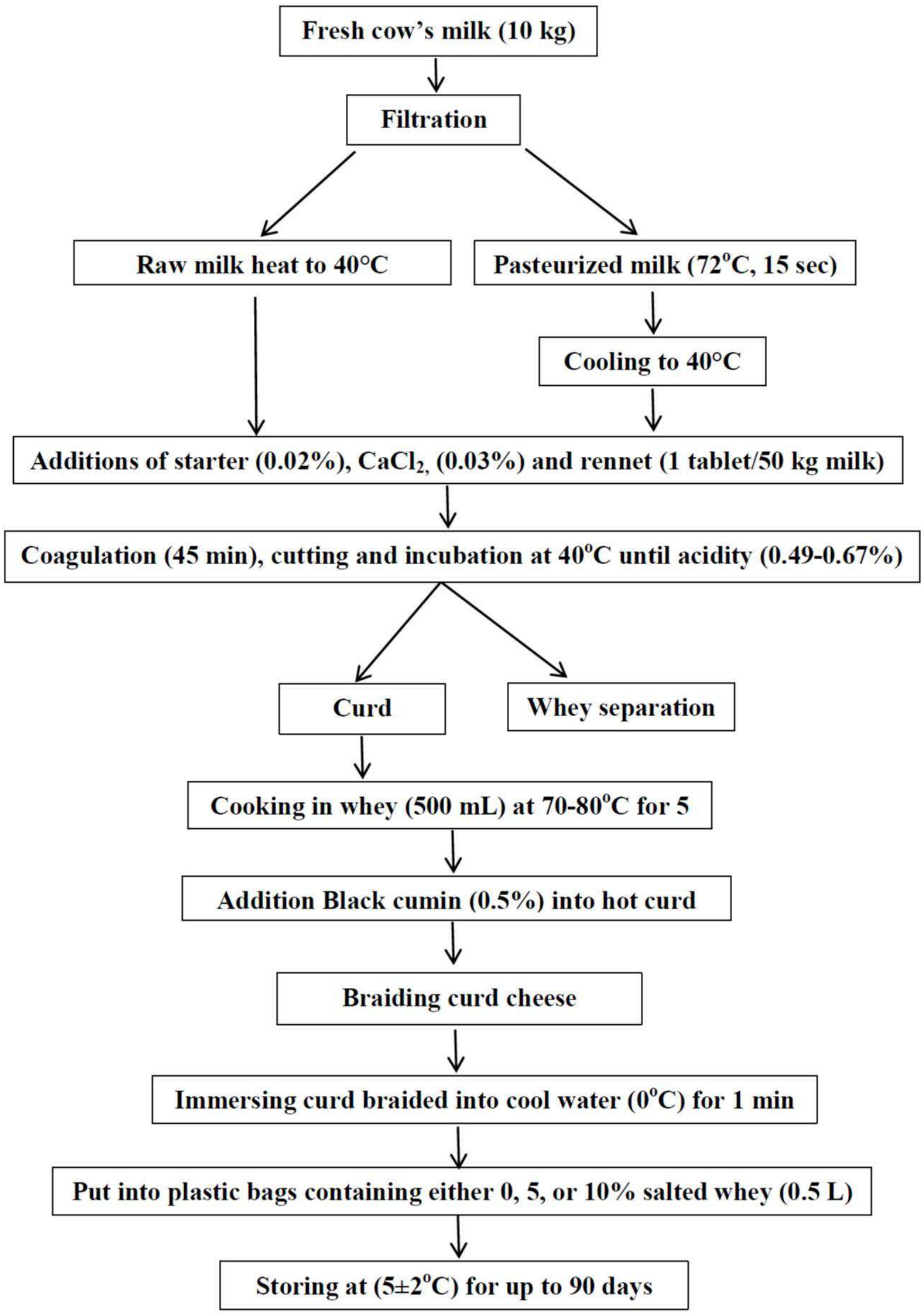

Figure 1. *Flowchart for the manufacturing of Sudanese braided cheese*

Mineral determination

The contents of Na, K, Mg, Ca, P, Fe, Cu, Co and Zn in the cheese sample were determined according to AOAC (2003). Stock solution of minerals was prepared by the dry ashing method that described elsewhere. Briefly, 2 g of cheese samples were weighed in dry crucible and placed in a muffle furnace for 4 h at 550°C. After cooling, samples were transferred to 250 mL beaker and then 12 mL of 5 N HCl and 3 mL of concentrated HNO_3 were added. The beaker was placed in a sand bath to boil for 10 min. Thereafter, 100 mL distilled water were added and allowed to boil for another 10 min. The contents were filtered through Whatman ashless filter paper No. 41. The filtrate was made up to 250 mL with double-distilled water and was used for determination of total minerals. For Na and K contents the flame photometer was used whereas for Ca and Fe, the Atomic Absorption Spectrophotometer (model Unicom 929 AAS, U.S.A) at 510 nm was used. As for the remaining elements (Zn, Cu, and Co) a PU 9100X model Atomic Absorption Spectrophotometer (Philips, Great Britain) was used to determine their contents using an air–acetylene flame by AAS method with deuterium background correction. For all elements the air and acetylene flow rates were kept at 13.5 L/min and 2.0 L/min, respectively. The correlation coefficients R^2 of the microelements Zn, Cu and Co were 0.9953, 0.9996 and 0.9872, respectively.

Statistical analysis

Three independent experiments, for a particular treatment and/or braided cheese type, were carried out and analyzed separately. The data collected were subjected to analysis of variance (ANOVA) and whenever appropriate the mean separation technique of Duncan (Steel and Torrie, 1980) was used. The SAS program (SAS, 2007) was employed to perform the general linear model (GLM) analysis at a $P < 0.05$.

Results and discussion

Effect of heat treatment on minerals content

The mineral content of BC processed from raw (BCRM) and pasteurized milk (BCPM) is shown in Table 1.

Table 1. *Effect of heat treatment on the mineral content of braided cheese*

Mineral	BCRM	BCPM	Change (%)
Ca (%)	0.59^{b}	0.81^{a}	37.29
Mg (%)	0.21^{a}	0.24^{a}	14.29
Na (%)	1.64^{b}	2.63^{a}	60.8
K (%)	0.17^{b}	0.51^{a}	200
P (ppm)	19.50^{b}	22.38^{a}	14.8
Fe (%)	0.92^{b}	1.10^{a}	19.6
Cu (%)	0.07^{b}	0.60^{a}	757
Zn (%)	0.04^{b}	0.09^{a}	125
Co (%)	0.26^{a}	0.19^{b}	-27

Mean followed by different superscripts letters in row is significantly different ($P < 0.05$).
BCRM=braided cheese processed from raw milk, BCPM=braided cheese processed from pasteurized milk.

Some minerals contents of BC fluctuated with the heat treatment. Except for Co and Mg contents, BCPM had always higher mineral content than BCRM. The two cheese types (BCRM and BCPM) had similar Mg content ($P > 0.05$). However, BCRM had significantly ($P < 0.05$) higher Co content than BCPM. Due to the heat treatment (milk pasteurization), the studied minerals (Ca, Mg, Na, K, P, Fe, Cu, Zn and Co) of braided cheese had changes by values that ranged between -27% to 757% compared to their values in braided cheese made from raw milk. Except Co, the increase of minerals content could be attributed to the denaturing effect of heat treatment on proteins, lipoproteins and glycoproteins. Such denaturation effect might have lead to the release of bound minerals. The minerals that showed the highest changes were Cu, K and Zn with 757%, 200%, and 125%, respectively. The higher enhancement of Zn and Cu could also be due to the denaturing effects of heat on proteins and particularly enzymes and thus release of these minerals. These two micronutrients exist in the structure of many enzymes. The enhancement of K could be attributed to the release of this mineral from the caseins due to the heat denaturing effect. Gonzalez-Martin *et al.* (2009) reported that the concentration of Mg does not present variations during the process of the cheese ripening over its average levels of concentration. The changes in minerals content of BC during heat treatment could be attributed to the degradation of protein and fat that in turn may lead to release of bound minerals (Fe, Ca, and P). The mineral compounds participate in the coagulation; influence the draining of the whey and the texture of the curd and on properties such as stability to heat and the capacity of coagulation (Patiño *et al*., 2005). The elevated concentration of Na throughout the ripening process with an average value of 7.93 g/kg is principally due to the addition of salt during the process and throughout ripening, coincides with that observed by Gambelli *et al.* (1999). The seasonality has a significant influence on the concentration of K, Mg and P. The seasonal variation in the composition of the milk, as is known, is due to changes in the bioavailability and quality of the pastures throughout the year and to an increase in the proteolytic activity associated with lactation period. Bakircioglu *et al.* (2011), investigated the concentrations of Cd, Co, Cr, Cu, Mn, Ni, Pb, Se, and Zn in cheese samples packaged in plastic and tin containers and he found considerable differences among their element contents.

The overall change in mineral content of the BC as the result of SC is shown on Table 2. With few exceptions, the general trend for the change was an increase in minerals content with the increase in SC. The elements that showed a negative change i.e. a decrease in content with the increase in SC were P, Zn and Co. The mineral that showed the biggest positive change were Na, K and Cu with 295%, 194% and 80% respectively. At 0 % SC, content of metals in BC were in the following order Fe > Na > Ca > Co > Mg > K > Zn > Cu. The elevated concentration in minerals content with the increase in SC could be attributed to absorption of the salt (NaCl) or high concentration of salt in whey might have stopped the migration of mineral from central curd. Particularly, during cheese ripening some of the mineral salts may migrate from the central part towards the external layer of the cheese block or vice versa (Gambelli *et al*., 1999).

Effect of salt concentration on minerals content

Table 2. *The changes in mineral content of braided cheese stored in whey with different salt concentration*

Mineral	Salt concentration (%) 0	5	10	Overall change %
Ca (%)	0.56[b]	0.66[b]	0.88[a]	57
Mg (%)	0.19[a]	0.26[a]	0.23[a]	21
Na (%)	0.83[c]	2.30[b]	3.28[a]	295
K (%)	0.18[c]	0.30[b]	0.53[a]	194
P (ppm)	23.51[a]	19.05[c]	20.27[b]	-14
Fe (%)	1.02[ab]	0.97[b]	1.05[a]	-3
Cu (%)	0.05[b]	0.06[b]	0.09[a]	80
Zn (%)	0.06[a]	0.07[a]	0.05[a]	-17
Co (%)	0.29[a]	0.20[b]	0.18[b]	-58

Means followed by different superscripts letters in each row are significantly different ($P < 0.05$)

Effect of storage periods on minerals content

Table 3 shows the changes in total minerals content of BC during ripening for up to 90 days. The Na, Ca, and Fe contents of BC increased significantly (P < 0.05) as storage periods progressed. Calcium did not show any change (P > 0.05) in content up to 60 days of storage thereafter its content increased significantly (P < 0.05). Sodium content showed a decline (P < 0.05) in the first 30 days before it returned to its initial value on 60 days of storage thereafter it showed a sharp increase (P < 0.05). Sodium and Ca findings of this study disagree with that of Abdalla and Hassan (2013) particularly on prolonged storage (90 & 180 days). The Mg content of BC declined (P < 0.05) on the first 30 days then it elevated (P <0.05) throughout the rest of storage period. The Cu and Zn of BC had similar (P > 0.05) values during storage period. The Mg, P and Co contents of BC declined as storage period advanced. In general the storage periods had significantly (P < 0.05) affected mineral content of BC. Gonzalez-Martin *et al.* (2009) reported that the duration of ripening had significant effects on the contents of all minerals with the exception of Zn, a phenomenon which could be due to different degrees of mobility of different elements.

Table 3. *Effect of the storage periods on mineral content of braided cheese*

Mineral	Storage periods (days) 0	30	60	90	Overall changes
Ca (%)	0.62 [b]	0.56 [b]	0.61 [b]	1.02 [a]	+
Mg (%)	0.34 [a]	0.18 [b]	0.18 [b]	0.21 [b]	-
Na (%)	1.40 [b]	1.03 [c]	1.36 [bc]	4.76 [a]	+
K (%)	0.32 [b]	0.08 [c]	0.10 [bc]	0.86 [a]	+
P (ppm)	22.49 [a]	22.47 [a]	21.0 [b]	17.83 [c]	-
Fe (%)	0.82 [d]	0.95 [c]	1.08 [b]	1.21 [a]	+
Cu (%)	0.06 [b]	0.07 [b]	0.09 [a]	0.06 [b]	+
Zn (%)	0.01 [bc]	0.07 [b]	0.17 [a]	0.01 [bc]	+
Co (%)	0.30 [a]	0.17 [b]	0.15 [bc]	0.27 [a]	-

Means followed by different superscripts letters in each row are significantly different ($P < 0.05$)

Effect of heat treatment and salt concentration on mineral content

The data in Table 4 shows the changes in total minerals content of BC as affected by heat treatment and three levels of salt. The minerals (Ca, Mg, Na, K, P, Fe, Cu, Zn, and Co) contents of BC were significantly ($P < 0.05$) affected by heat treatment and SC (0%, 5%, and 10%)**.** With few exceptions, BCPM had always higher ($P < 0.05$) mineral contents than BCRM. This is particularly true in the cases of Na, Ca, K, and Mg contents. The rest of minerals (P, Fe, Cu, Zn, and Co) of BCRM and BCPM showed various degrees of change, however Cu and Zn showed similar contents in both cheeses. BCRM had significantly ($P < 0.05$) or numerically ($P > 0.05$) higher Co values than BCPM.

Table 4. *Effect of heat treatment and salt concentration on minerals content of braided cheese*

Mineral	**BCRM**			**BCPM**		
	Salt concentration (%)					
	0	**5**	**10**	**0**	**5**	**10**
Ca (%)	0.60 [cd]	0.51 [d]	0.66 [c]	0.52 [d]	0.82 [b]	1.11 [a]
Mg (%)	0.20 [b]	0.26 [a]	0.16 [c]	0.18 [b]	0.26 [a]	0.29 [a]
Na (%)	0.71 [d]	1.76 [c]	2.45 [b]	0.95 [d]	2.84 [b]	4.11 [a]
K (%)	0.16 [c]	0.13 [c]	0.22 [cd]	0.20 [d]	0.48 [b]	0.85 [a]
P (ppm)	21.47 [b]	18.89 [c]	18.15 [c]	25.55 [a]	19.20 [c]	22.39 [b]
Fe (%)	0.61 [d]	1.05 [b]	1.10 [b]	1.42 [a]	0.89 [c]	1.01 [b]
Cu (%)	0.05 [a]	0.05 [a]	0.13 [b]	0.06 [a]	0.07 [a]	0.05 [a]
Zn (%)	0.03 [b]	0.03 [b]	0.05 [b]	0.10 [a]	0.12 [b]	0.06 [ab]
Co (%)	0.33 [a]	0.21 [bc]	0.23 [b]	0.24 [b]	0.19 [c]	0.12 [d]

Means followed by different superscripts letters in each row are significantly different ($P < 0.05$).
BCRM=braided cheese processed from raw milk.
BCPM= braided cheese processed from pasteurized milk

Heat treatment had led to greater Fe content (1.42 ppm). With or without heat treatment, the concentrations of Cu, Na, and K increased ($P < 0.05$) with the increase in SC. Dairy products, including cheese, contribute little dietary iron (Brien and O'Connor, 2004). Iron deficiency is commonly observed in both developing and developed countries. Hence, there has been interest in fortifying dairy products with Fe to enhance their nutritional value. Cheddar and processed cheeses were successfully fortified with Fe (Zhang and Mahoney, 1991).

Effect of salt concentration and storage period on mineral content

The combined effects of SC and storage period minerals content of BC is shown in Table 5. The contents of Ca, Mg, Na, K, P, Fe, Cu, Zn, and Co in BC fluctuated as it was ripened in different SC and storage periods**.** The Ca content of BC stored in unsalted whey (0%) was significantly ($P <$

0.05) increased as storage periods progressed but the cheese stored in 5% salted whey (SW) decreased and then increased sharply to 1.18% at the end of storage period. The highest value of Ca (1.29%) was found in the cheese stored in 10% SW after 90 days of storage. With the exception of day 0, Mg contents of BC stored in SW with different salt concentrations were similar and remained constant throughout the storage period tested. The Na content of BC, except that was stored in 0 % salt whey, increased significantly (P < 0.05) as storage periods progressed. At the end of storage period, the BCs stored in 5% and 10% SW showed the highest Na concentrations of 5.96% and 6.25%, respectively. The K, P, and Fe contents of BC stored in different SW concentrations varied significantly (P < 0.05) as storage periods progressed. A wide range of Na levels were found in cheese due to different amounts of salt added during cheese making. In general, the salt content of natural cheeses tends to be lower than that of many processed cheeses (Brien and O'Connor, 2004).

Table 5. *Effect of salt concentration and storage periods on minerals content of braided cheese*

Mineral	Salt concentration (%)											
	0				5				10			
	Storage period (days)											
	0	30	60	90	0	30	60	90	0	30	60	90
Ca (%)	0.44^{c}	0.56^{bc}	0.64^{b}	0.61^{b}	0.70^{b}	0.39^{c}	0.38^{c}	1.18^{a}	0.71^{b}	0.73^{b}	0.80^{b}	1.29^{a}
Mg (%)	0.32^{a}	0.18^{b}	0.13^{b}	0.15^{b}	0.37^{a}	0.18^{b}	0.23^{ab}	0.27^{ab}	0.33^{a}	0.19^{b}	0.18^{b}	0.20^{b}
Na (%)	0.35^{f}	0.56^{f}	0.33^{f}	2.08^{c}	1.62^{cd}	0.75^{f}	0.87^{f}	5.96^{a}	2.25^{c}	1.77^{c}	2.87^{b}	6.25^{a}
K (%)	0.20^{f}	0.17^{f}	0.03^{g}	0.34^{d}	0.32^{d}	0.04^{g}	0.04^{g}	0.82^{b}	0.45^{c}	0.04^{g}	0.22^{f}	1.43^{a}
P (ppm)	22.17^{c}	25.66^{a}	24.32^{b}	21.89^{cd}	20.93^{d}	19.03^{f}	19.70^{f}	16.54^{g}	24.35^{b}	22.72^{c}	18.97^{f}	15.06^{h}
Fe (%)	0.93^{gh}	0.67^{i}	1.45^{b}	1.02^{f}	1.02^{f}	0.83^{h}	1.16^{d}	0.88^{h}	0.51^{j}	1.35^{c}	0.64^{i}	1.73^{a}
Cu (%)	0.06^{b}	0.04^{b}	0.05^{b}	0.06^{b}	0.04^{b}	0.06^{b}	0.09^{ab}	0.05^{b}	0.07^{b}	0.10^{a}	0.14^{a}	0.06^{b}
Zn (%)	0.01^{b}	0.05^{b}	0.19^{a}	0.01^{b}	0.01^{b}	0.03^{b}	0.24^{a}	0.02^{b}	0.00^{b}	0.12^{b}	0.08^{b}	0.02^{b}
Co (%)	0.35^{a}	0.21^{b}	0.32^{a}	0.27^{ab}	0.32^{a}	0.13^{b}	0.05^{c}	0.32^{a}	0.22^{b}	0.17^{b}	0.08^{bc}	0.24^{b}

Means followed by different superscripts letters in the same row are significantly different (*P* < 0.05).

The Cu and Zn content of the cheese stored in different SW were similar during storage period except at 60 days which showed the highest values. This was possibly due to diffusion of salt from SW into the curd, or high salt concentration whey stopped the migration of some minerals from the central curd. The Co content of BC stored in 0%, 5% and 10% SW had no significant (P > 0.05) effect at day 0 of storage. Cheese is an important dietary source of several minerals, in particular Ca, P and Mg. A 100 g serving of hard cheese provides approximately 800 mg Ca (Brien and O'Connor, 2004).

Effect of heat treatment and storage period on minerals content

The changes in total minerals content of BC as affected by heat treatment and storage periods is shown in Table 6. The minerals content of BC was significantly (P ≤ 0.05) affected by heat treatment and storage period. The Ca, Mg, Na, and K content of BCRM increased significantly throughout the storage period except for the first 30 days of storage. The greatest value was observed at the end of storage period, with the following order; Na > K > Ca > Mg. Storage period had no effect (P > 0.05) on Zn content except with BCPM at day 60 of storage. In BCRM, the minerals that had the highest value were Fe, Cu, and Zn. On the other hand, the Cu and Zn content of BCPM had similar (P >0.05) values. During cheese ripening some of the mineral salts may migrate from the central part towards the external layer of the cheese block or vice versa (Gambelli *et al.*, 1999). The mineral compounds participate in the coagulation; influence the draining of the whey and the texture of the curd and on their properties such as stability to heat and the capacity of coagulation (Patiño *et al.*, 2005).

Table 6. *Effect of heat treatment and storage periods on minerals content of braided cheese*

Mineral	BCRM				BCPM			
	Storage period (days)							
	0	30	60	90	0	30	60	90
Ca (%)	0.46^{c}	0.50^{bc}	0.56^{bc}	0.83^{b}	0.77^{b}	0.61^{b}	0.66^{b}	1.22^{a}
Mg (%)	0.31^{a}	0.16^{b}	0.18^{b}	0.20^{ab}	0.36^{a}	0.21^{a}	0.19^{b}	0.21^{a}
Na (%)	1.27^{c}	0.61^{d}	0.82^{d}	3.87^{b}	1.54^{c}	1.45^{c}	1.89^{c}	5.64^{a}
K (%)	0.24^{d}	0.09^{g}	0.03^{g}	0.32^{c}	0.40^{b}	0.07^{g}	0.17^{f}	1.40^{a}
P (ppm)	16.17^{d}	20.74^{c}	21.08^{c}	20.03^{c}	28.80^{a}	24.20^{b}	20.91^{c}	15.63^{d}
Fe (%)	0.66^{f}	0.84^{d}	0.84^{d}	1.33^{a}	0.97^{c}	1.05^{b}	1.32^{a}	1.09^{b}
Cu (%)	0.05^{b}	0.09^{a}	0.11^{a}	0.05^{b}	0.06^{ab}	0.04^{b}	0.07^{ab}	0.06^{ab}
Zn (%)	0.00^{b}	0.08^{b}	0.06^{b}	0.01^{b}	0.01^{b}	0.06^{b}	0.28^{a}	0.02^{b}
Co (%)	0.33^{a}	0.21^{c}	0.23^{bc}	0.27^{b}	0.26^{b}	0.13^{d}	0.07^{f}	0.28^{a}

Mean followed by different superscripts letters in each row are significantly different ($P < 0.05$).
BCRM=braided cheese processed from raw milk.
BCPM= braided cheese processed from pasteurized milk

Effect of heat treatment, salt concentration and storage period on minerals content

The interactive effect of heat, salt and storage period on the minerals content of BC is shown in Table 7. The Ca content of BC ripened in SW increased (P < 0.05) as the storage time progressed. The Ca content of BCRM stored in 0% SW increased gradually from 0.52 % to 0.71 % after 90 days. On the other hand, the BCPM stored in 5% SW, produced the lowest value of Ca (0.17 %) in comparison with all types of BC treatments. The Ca content of BCPM stored in 10 % SW decreased from 1.0% in the first day to 0.89% after 30 days then increased to 1.52% after 90 days of storage. A similar finding was reported earlier by Buruiana and Zeidan (1982). Amer *et al*. (1979) reported a decrease in Ca content of kashkaval cheese during ripening. The decrease in Ca of Muddaffara cheese kept at room temperature was significantly (P < 0.05) higher than that stored in cold store temperature. Samples of cheese stored in low level of salt recorded lower Ca content compared to those stored in high level of salt which had the highest Ca in cheese curd. Abd El Razig *et al*. (2002) noted that increasing level of salt in brining whey to 15 and 20% significantly lowered the rate of Ca content decline during storage (260 mg/100 g), with pronounced effect at low temperature storage (400 mg/ 100 g). The higher loss of Ca content in BC stored at low salt level could be attributed to the high acidity of cheese samples (Buruiana and Zeidan, 1982). El-Abd *et al.* (1982) found that the Ca content of both cow′s and buffalo′s casein and para casein dissolved by increased acidity. They also found that the binding of Ca to casein increased as the pH increased. Egyptian processed cheddar cheese had a Ca content of 548 mg/100g (El-Sonbaty *et al*., 1998). The Mg content of BC decreased significantly (P < 0.05) as the storage time progressed. The Mg content of BCRM stored in 0% SW decreased gradually from 0.31% to 0.13 % after 60 days and then increased slightly to 0.15%. On the other hand the Mg content of BCPM stored in 0 % SW decreased from 0.32% to 0.13% after 60 days of storage and then increased slightly to 0.15% at the end of storage periods (90 days).

The Na content of BCRM stored in 0% SW increased from 0.15% to 0.40 % after 30 days and then increased to 1.96% at the end of storage periods. On the other hand, the Na content of BCPM stored in 0 % SW decreased to 0.33% at 60 days and then increased to 2.19% at the end of storage periods. The Na content of BCRM stored in 10% SW increased from 2.28 % in the first day to 5.13 % at the end of storage periods (90 days).

Table 7. *Effect of heat treatment, salt concentration and storage periods on minerals content of braided cheese*

Heat treatment	Salt conc. (%)	Storage period (days)	Mineral content (%)								
			Ca	Mg	Na	K	P (ppm)	Fe	Cu	Zn	Co
BCRM	**0**	**0**	0.52^{bc}	0.31^{c}	0.15^{g}	0.16^{d}	12.48^{f}	0.64^{i}	0.05^{c}	0.01^{b}	0.28^{d}
		30	0.57^{b}	0.23^{b}	0.40^{g}	0.19^{d}	24.40^{c}	0.58^{i}	0.05^{c}	0.09^{b}	0.26^{d}
		60	0.61^{b}	0.13^{b}	0.32^{g}	0.04^{f}	24.24^{c}	0.54^{i}	0.05^{c}	0.00^{b}	0.55^{a}
		90	0.71^{b}	0.15^{b}	1.96^{d}	0.27^{d}	24.75^{c}	0.69^{i}	0.06^{c}	0.00^{b}	0.24^{d}
	5	**0**	0.34^{c}	0.40^{a}	1.37^{df}	0.18^{d}	16.64^{d}	0.97^{g}	0.04^{c}	0.00^{b}	0.37^{c}
		30	0.37^{c}	0.12^{b}	0.63^{g}	0.05^{f}	18.98^{d}	0.59^{i}	0.07^{c}	0.00^{b}	0.10^{f}
		60	0.59^{b}	0.24^{a}	0.52^{g}	0.03^{f}	21.24^{d}	1.41^{c}	0.05^{c}	0.11^{b}	0.05^{f}
		90	0.73^{b}	0.29^{a}	4.53^{b}	0.25^{cd}	18.69^{d}	1.23^{f}	0.05^{c}	0.00^{b}	0.33^{c}
	10	**0**	0.53^{b}	0.21^{a}	2.28^{d}	0.39^{c}	19.38^{d}	0.38^{i}	0.06^{c}	0.00^{b}	0.33^{c}
		30	0.57^{b}	0.13^{b}	0.79^{g}	0.04^{f}	18.83^{d}	1.36^{d}	0.15^{b}	0.14^{b}	0.26^{d}
		60	0.47^{c}	0.16^{a}	1.63^{df}	0.01^{f}	17.76^{d}	0.58^{i}	0.25^{a}	0.06^{b}	0.08^{f}
		90	1.05^{a}	0.16^{a}	5.13^{c}	0.43^{c}	16.64^{d}	2.07^{b}	0.05^{c}	0.01^{b}	0.24^{d}
BCPM	**0**	**0**	0.35^{c}	0.32^{a}	0.54^{g}	0.23^{d}	31.86^{a}	1.21^{f}	0.07^{c}	0.00^{b}	0.42^{b}
		30	0.54^{b}	0.12^{ab}	0.72^{g}	0.15^{d}	26.92^{c}	0.76^{i}	0.04^{c}	0.01^{b}	0.17^{df}
		60	0.67^{b}	0.14^{a}	0.33^{g}	0.02^{f}	24.40^{c}	2.36^{a}	0.05^{c}	0.37^{a}	0.09^{f}
		90	0.50^{bc}	0.15^{a}	2.19^{d}	0.41^{c}	19.03^{d}	1.35^{c}	0.07^{c}	0.02^{b}	0.29^{d}
	5	**0**	1.06^{ab}	0.33^{a}	1.88^{df}	0.46^{c}	25.21^{c}	1.07^{g}	0.05^{c}	0.01^{b}	0.27^{d}
		30	0.40^{c}	0.24^{a}	0.87^{gf}	0.03^{f}	19.08^{d}	1.07^{g}	0.05^{c}	0.05^{b}	0.15^{f}
		60	0.17^{c}	0.23^{a}	1.22^{df}	0.05^{f}	18.15^{d}	0.90^{g}	0.14^{b}	0.37^{b}	0.05^{f}
		90	1.63^{a}	0.25^{a}	7.38^{a}	1.80^{b}	14.38^{f}	0.53^{i}	0.05^{c}	0.03^{b}	0.31^{d}
	10	**0**	1.00^{ab}	0.44^{a}	2.21^{d}	0.50^{c}	29.32^{b}	0.63^{i}	0.07^{c}	0.01^{b}	0.10^{f}
		30	0.89^{b}	0.26^{a}	2.76^{d}	0.03^{f}	26.60^{c}	1.33^{c}	0.05^{c}	0.11^{b}	0.08^{f}
		60	1.13^{a}	0.21^{a}	4.13^{b}	0.43^{c}	20.17^{d}	0.69^{i}	0.03^{c}	0.09^{b}	0.07^{f}
		90	1.52^{a}	0.24^{a}	7.36^{a}	2.42^{a}	13.47^{f}	1.39^{cd}	0.07^{c}	0.02^{b}	0.24^{d}

Mean followed by different superscripts letters in each column are significantly different ($P < 0.05$)
BCRM=braided cheese processed from raw milk.
BCPM= braided cheese processed from pasteurized milk.

These results are in agreement with Abd El Razig *et al*. (2002) who reported that Na content of low salt cheese (10%) was significantly lower than both medium (15%) and high level (20%) of salt. Cheese stored at cold temperature kept in low salt gave the lowest Na content than that of medium salt cheese and high salt cheese. Prokopek *et al*. (1990) reported low Na content of Edam semi-hard cheese when ripened in low salt brines. The higher Na content of samples stored at room temperature was attributed to the higher loss in their moisture content. The elevated concentration of Na (7.93 g/kg) throughout the ripening process is principally due to the addition of salt. Such observation coincides with that of Gambelli *et al*. (1999). The K and P contents of BCRM stored in 0% SW increased in the first day from 0.16% to 0.27 % and from 12.48 ppm to 24.75ppm, respectively after 90 days of storage. On the other hand the K and P contents of BCPM stored in 5% SW decreased from the first day to 60 days and then increased at the end of storage period. The P content of BCPM in 10 % SW decreased from 29.32 ppm in the first day to 20.17ppm at day 60 respectively. Storage period had no effect ($P > 0.05$) on the Zn content except with BCRM stored in 0% SW at day 60 of storage. The Cu content of BCRM was not changed ($P \geq 0.05$) with storage period. The highest value of Cu (0.25%) and Co (0.55%) were found in BCRM stored in 10% and 0% SW after 60 days of storage respectively. The change occurred in minerals content of BC stored in SW during storage period, is probably due to the decomposition of different components of BC by proteolysis and lipolysis.

Conclusions

Both pre-processing (heat treatment) and ripening conditions (salt level and duration) had substantial effects on macro and micro minerals contents of BC. Braided cheese ripened in 10% SW had significantly ($P < 0.05$) higher mineral contents compared to that ripened in 0% or 5% SW. Generally the three factors tested exhibited significant interactions on the minerals contents of the BC. With or without heat treatment, the concentrations of Cu, Na, and K increased ($P < 0.05$) with the increase in salt concentration. This piece of work revealed the effects of different processing conditions on the potentiality of SBC as a good source of some micronutrients (minerals) important for consumer health. Further study shall specifically focus on the microbiological aspects of braided cheese made from raw milk and ripened in low salt whey.

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