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ELECTRICAL CONDUCTIVITY OF RAW MILK AND KAREISH CHEESE

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ABSTRACT

The electrical conductivity (EC) was measured in 42 samples of individual raw milk and 15 samples of Kareish cheese collected from outskirts of Assiut province. The average levels of EC in raw milk samples were 3.59±0.47 for cold months and 2.49±0.39 mS/cm at 25°C for warm months, respectively. There was a significant variation between EC in both cold and warm months. Also the contribution and correlations of the various components in cow's milk to its EC has been studied. The average level of EC in cheese samples were 5.89±0.24 mS/cm at 25°C. Approximately 19.10% of cold months milk samples, 9.52% of warm month's milk samples and 46.67% of Kareish cheese samples recorded an EC value ranged from 6.00-8.00 mS/cm. However, presence of NaCl in cheese whey sharply increases EC. The results suggested that clinical mastitis could be detected earlier by measuring changes in EC of milk. Also a considerable seasonal variation of EC in raw milk was demonstrated.

INTRODUCTION

Milk has conductive properties because it is rich in charged compounds, especially mineral and salts. The EC of milk is mainly due to its soluble salt. Electrical conductivity measurements have been used extensively in the food industry; for example to detect contamination of water and to monitor microbial growth and metabolic activity (Curda and Plockova, 1995). The conductivity of milk and dairy products has been studied for more than 40 years to provide values of the fat, water and protein content (Mabrook and Petty, 2002) and to detect mastitis (Nielen *et al.*, 1992). Many factors can affect the conductivity, such as stage of lactation, season of the year, animal breed and feed which affect the distribution of salt fractions in milk between soluble and colloidal phases and thus the number of free conducting ions in the milk (Fox and McSweeney, 1998 and Mabrook and Petty, 2003) and the rise of 1 mS of the mean electrical conductivity caused a decline of 0.88 kg/d in milk production (Nielen *et al.*, 1993).

Electrical conductivity is one of the testing methods used to determine quantities such as soluble salts (Crow, 1994), protein content in whey powder (Zhuang *et al.*, 1997), and casein content during renneting (Dejmek, 1989). It can also be used as a diagnostic of intramammary infection (Woolford *et al.*, 1998) as well as measurement of EC has long been used as a quality control indicator. Also EC measurement was used as a simple direct measurement method to determined whey demineralization throughout conventional electrodialysis processes with monopolar membranes (Lin Teng Shee *et al.*, 2005).

In fermented milk, EC is determined by lactic acid production, and by the concentration of solubilized anions and cations which are more soluble in milk at low than high pH (Nielen *et al.*, 1992). The chemical structure of a material affects its electrical conductivity. Protein has a positive influence on electrical conductivity (St-Gelais *et al.*, 1995), the electrical conductivity of milk decreases as the concentration of fat and lactose increases (Prentice, 1962). Typically the electrical conductivity of milk at 25°C is in the range from 4.0 to 5.5 mS/cm (Nielen *et al.*, 1992) and also increases with temperature (Loveland, 1986).

The contribution of proteins and peptides is of minor importance. In addition, pH decrease causes hydrogenation of monohydrogen phosphate ions to dihydrogen phosphate ions, which have lower molar conductivity. Thus, addition of lactic acid to a phosphate buffer solution (pH 6.5) decreases conductivity. However, fermentation of lactose to lactic acid sharply increases conductivity; also, acidification of milk increases conductivity sharply (Mucchetti *et al.*,1994). In a dairy blend, the lactic acid production, the soluble Ca, and protein concentrations affected the EC (St-Gelais *et al.*, 1995).

Production and composition of mastitic milk was altering (Deluyker, 1991). Lactose and K^+ contents were decreased, and concentrations of Na^+ and Cl^- were increased. The altered concentration of Na^+, K^+ and Cl^- causing increase the EC of mastitic milk (Kitchen *et al.*, 1980). In addition to mastitis, other factors that cause change in the ionic content of milk have an influence on the EC of milk including variation among cows, days within cows, stage of lactation, parity, and herd differences (Nielen *et al.*, 1992 and Biggadike *et al.*, 2000).

The objective of this study was to investigate the effect of composition of both raw milk and white soft cheese (Kareish) mostly consumed in Assiut Governorate on its electrical conductivity and evaluate their compliance with international regulation.

MATERIALS AND METHODS

1. Collection of samples

A total of 42 individual raw cows' milk samples were collected from Mankabad village near Assiut city during cold and warm months over one year and 15 samples of white soft cheese (Kareish) were obtained from Dronka village near Assiut city.

2. Chemical and physical analysis

2.1 Ash content, titratable acidity and pH value

Ash contents and titratable acidity were determined according to the method described in A.O.A.C. (2000). The pH values of milk and cheese were determined using glass electrode pH meter (ICM 41150) as described by A.O.A.C. (2000).

2.2 Moisture

Moisture contents of experimental milk and cheese were determined according to IDF (1982).

2.3 Fat content

The fat contents of milk and cheese were determined according to the methods of IDF (1986).

2.4 Protein content

Total nitrogen contents were determined by semi micro kjeldahl method as described by IDF (1993).

2.5 Lactose content

Lactose content was determined according to the method described by Barnett and Tawab (1957).

2.6 Salt content

For the determination of salt %, the method adopted by Pearson (1975) was used.

2.7 EC value

The electrical conductivity was measured according to Mijnen *et al.* (1982) by conductometer model (HANNA-H18820N) in mS/cm at 25˚C.

3. Statistical analysis

Results were evaluated statistically using the software program; the SAS system for windows, release 8.02 TS level 02M0, SAS Institute Inc., Cary, NC, USA (SAS, 1999).

RESULTS AND DISCUSSION

Results in Table 1 shows that the mean value of EC in raw milk during the cold and the warm months were ranged from 1.27 to 7.23 and 1.31 to 7.60 with averages of 3.59 ± 0.47 and 2.49±0.39 mS/cm at 25°C, respectively. The average of EC of raw milk during cold months was higher than that of warm months. This may be due to the higher contents of protein, ash and acidity of milk (Table, 1). These finding was in agreement with those obtained by Prentice (1962), Sheldrake *et al.* (1983), Nielen *et al.* (1992 and 1993), St-Gelais *et al.* (1995), and Spakauskas *et al.* (2006). Statistically significant differences in EC were demonstrated between cold and warm months (T. test > 0.05) (Table, 2).

Table 1. The chemical composition and incidence of electrical conductivity (mS/cm at 25°C) of raw milk during cold and warm months.

Observations	Cold months		Warm months	
	Range	Average	Range	Average
EC	1.27-7.23	3.59 ± 0.47	1.31-7.60	2.49 ± 0.39
Moisture %	82.38 - 90.38	87.73 ± 0.56	85.69-90.27	87.28 ± 0.29
T.S %	9.62– 17.62	12.35± 0.57	9.73-14.30	12.67± 0.31
Fat %	1.00-4.90	3.21 ± 0.22	1.60-4.90	3.51 ± 0.24
Lactose%	2.15-5.45	3.34 ± 0.19	2.55-5.85	3.83 ± 0.22
Protein %	2.95– 4.98	3.84± 0.11	1.95-4.51	3.38 ± 0.19
Ash %	0.53- 0.88	0.69 ± 0.02	0.25-0.83	0.66± 0.03
Acidity %	0.15- 0.25	0.19 ± 0.01	0.15-0.22	0.18 ± 0.01
pH	6.28-6.68	6.50 ± 0.03	6.35-6.74	6.60 ± 0.03

It was found that the mean value of moisture content %, T.S %, fat %, lactose %, protein %, ash %, acidity % and pH of the milk of cold season were 87.73 ± 0.56, 12.35 ± 0.57, 3.21± 0.22, 3.34± 0.19, 3.84± 0.11, 0.69 ± 0.02, 0.19 ± 0.01, and 6.50± 0.03 while that for samples of warm months were 87.28 ± 0.29, 12.67± 0.31, 3.51± 0.24, 3.83±0.22, 3.38 ±0.19, 0.66±0.03, 0.18±0.01 and 6.60±0.03, in the same respect. There were non-significant differences in the raw milk components among cold and warm months ("t" test) Table (2). These results were in agreement with those obtained by Mabrook and Petty (2003).

Statistically no significant differences in moisture, fat, lactose, protein, ash, acidity contents and pH values were demonstrated between cold and warm months milk samples (T. test) as shown in Table (2).

Table 2. Statistical analysis of cold and warm raw milk.

Observations	Months	Mean	Standard deviation	Standard error	T. test	Significant
EC	Cold	3.59	2.14	0.47	2.46*	0.02*
	Warm	2.49	1.79	0.39		
Ash %	Cold	0.69	0.09	0.02	1.17	0.26
	Warm	0.66	0.12	0.03		
Moisture %	Cold	87.73	20581	0.56	0.72	0.48
	Warm	87.28	1.37	0.29		
Fat %	Cold	3.21	1.00	0.22	0.97	0.34
	Warm	3.51	1.09	0.24		
Acidity %	Cold	0.19	0.03	0.01	1.56	0.14
	Warm	0.18	0.19	0.004		
pH	Cold	6.50	0.11	0.03	1.71	0.10
	Warm	6.56	0.12	0.03		
Lactose %	Cold	3.34	0.90	0.19	1.50	0.73
	Warm	3.83	1.02	0.22		
Protein %	Cold	3.84	0.49	0.11	1.89	0.15
	Warm	3.38	0.85	0.19		
T.S %	Cold	12.35	2.53	0.57	0.53	0.60
	Warm	12.67	1.39	0.31		

Data in Table 3 show that 19.10% and 9.52% of both cold and warm month's milk respectively recorded an EC ranged from 6-8 mS/cm. These results were less than those obtained by Nazem and Azab (1998) who found that 72.25 % and 61.68% of cow's and buffalo's were infected with mastitis.

Table 3. The intervals of electrical conductivity (mS/cm at 25°C) in raw milk samples during cold and warm months.

Intervals	Cold months		Warm months	
	No	%	No	%
Zero- 2	8	38.10	14	66.67
2 - 5	6	28.57	4	19.05
5 - 6	3	14.29	1	4.76
6-8	4	19.10	2	9.52
Total	21	100%	21	100%

On the other hand, the EC value of Kareish cheese samples was ranged from 4.20 to 7.10 with mean value of 5.89±0.24 mS/cm at 25°C. These finding is nearly coincided with the results of Robbins and Lehrsch (1992). They found that the whey of Cottage cheese has an electrical conductivity (EC) of 6-10 dS m^{-1}.

Also the mean values of moisture, T.S, fat, lactose, protein, ash, acidity, NaCl % and pH value were 64.39±1.97, 35.61±1.97, 2.80±0.46, 0.96 ± 0.20, 20.94±2.23, 3.92±0.27, 2.22±0.34, 8.66±0.69 and 4.65±0.27, respectively. The present data are in agreement with those reported by Abd-El-Ghany (2002), Abd-Alla (2004) and Metwalli (2011).

Table 4. The chemical composition and electrical conductivity of Kareish cheese.

Observations	Commercial Kareish cheese			
	Range	Average	Standard deviation	Standard error
EC	4.20 - 7.10	5.89	0.92	0.24
Ash %	2.64-5.72	3.92	1.03	0.27
Moisture %	52.65-73.56	64.39	7.65	1.97
T.S %	26.44-47.36	35.61	7.65	1.97
Fat %	1-6	2.80	1.78	0.46
Protein %	11.29-37.68	20.94	8.64	2.23
Acidity %	0.25-3.65	2.22	1.32	0.34
pH	3.53-6.66	4.65	1.05	0.27
Lactose %	0.15-2.45	0.96	0.77	0.20
NaCl %	3.39-12.29	8.66	2.69	0.69

EC values presented in Table (5) concluded that 46.67% of cheese samples had 6-8 mS/cm and 20% of cheese recorded 2-5 mS/cm. These variations may be due to salt content in cheese.

Table 5. The intervals of electrical conductivity (mS/cm at 25°C) in Kareish cheese samples collected from (Dronka) Assiut.

EC value	Commercial Kareish cheese	
	No	%
Zero- 2	0	0
2 – 5	3	20.0
5 – 6	5	33.33
6-8	7	46.67
Total	15	100

Data in Table 6 revealed the correlations between chemical composition and EC value of raw milk samples during cold months. The results showed that there were non-significant positive correlation between EC value and milk constitutes including ash, moisture, fat, acidity, and protein, while negative correlation had been found among EC and pH, T.S and lactose. These results were in agreement with those reported by St-Gelais *et al.* (1995) and Therdthai & Zhou (2001).

Data in Table 7 presented the correlation between the chemical composition of raw milk during warm months and its EC measurements. The results showed that ash, moisture, acidity, protein and lactose had non-significant positive with EC value, and negative correlation was found with non-significantly EC value and fat and T.S. Moreover, pH values had a negative highly significant correlation with EC. These results in agreement with those reported by Mucchetti *et al.* (1994).

Table 6. The correlations between chemical composition and incidence of electrical conductivity (mS/cm at 25 °C) of raw milk samples during cold months.

Observations	EC	Ash %	Moisture %	Fat %	Acidity %	pH	Protein %	Lactose %	T.S %
EC	1	0.13	0.42	0.23	0.002	- 0. 36	0.032	- 0.35	- 0.41
Ash %		1	0.054	0.110	0.254	0.039	0.290	- 0.21	- 0.23
Moisture %			1	- 0.17	- 0.11	- 0.02	- 0.06	-0.75**	-0.99**
Fat %				1	- 0.01	- 0.02	0.13	0.23	- 0.05
Acidity %					1	-0.74**	0.46*	- 0.09	0.04
pH						1	- 0.29	0.08	0.06
Protein %							1	0.09	0.04
Lactose %								1	0.76**
T.S %									1

***Correlation is significant at the 0.05 level.**
**** Correlation is significant at the 0.01 level.**

Table 7. The correlations between chemical composition and incidence of electrical conductivity (mS/cm at 25°C) of raw milk samples during warm months.

Observations	EC	Ash %	Moisture %	Fat %	Acidity %	pH	Protein %	Lactose %	T.S %
EC	1	0.03	0.39	-0.34	0.25	-0.57**	0.42	0.19	-0.39
Ash %		1	0.16	0.13	-0.1	0.08	-0.03	-0.59**	-0.16
Moisture %			1	-0.49*	-0.09	0.37	0.09	-0.26	-1.00**
Fat %				1	-0.05	-0.01	-0.08	-0.15	0.49*
Acidity %					1	-0.68**	-0.38	0.06	0.09
pH						1	0.28	0.03	-0.37
Protein %							1	0.02	-0.09
Lactose %								1	0.26
T.S %									1

***Correlation is significant at the 0.05 level.**
**** Correlation is significant at the 0.01 level.**

Data in Table 8 shows the correlations between the chemical composition and EC of Kareish cheese whey. The results revealed that there were a positive influence with non significantly difference among ash, moisture, fat and acidity, on EC, where as the Nacl had highly positive correlation effect on the conductivity. These results in accordance with Mucchetti *et al.* (1994) who found that addition of Nacl to milk caused an increase in conductivity. On the other hand, pH, T.S, protein and lactose had a negative correlation with non significantly differences. These results were pin agreement with those found by St- Gelais *et al.* (1995).

Table 8. The correlations between chemical composition and incidence of electrical conductivity (mS/cm at 25 °C) of Kareish cheese samples.

Observations	EC	Ash %	Moisture %	T.S %	Fat %	Acidity %	pH	Protein %	Lactose %	Salt %
EC	1	0.25	0.07	-0.07	0.10	0.06	-0.05	-0.15	-0.11	0.86**
Ash %		1	0.06	-0.06	0.19	-0.52*	0.53*	-0.19	0.34	-0.16
Moisture %			1	-1.00**	0.02	-0.26	0.34	-0.74**	-0.10	0.46
T.S %				1	-0.02	0.26	-0.34	0.74**	0.10	-0.46
Fat %					1	-0.19	0.12	0.02	-0.33	0.35
Acidity %						1	-0.97*8	0.61*	-0.38	0.20
pH							1	-0.61*	0.39	-0.14
Protein %								1	0.02	-0.32
Lactose %									1	-0.47
Salt %										1

***Correlation is significant at the 0.05 level.**
**** Correlation is significant at the 0.01 level.**

CONCLUSIONS

It appeared from the foregoing results that there was a significant variation between EC in both cold and warm months. This may be due to the higher contents of protein, ash and acidity of milk. The results of this study suggested that electrical conductivity can be used to detect the infection of mastitis in milk and prediction of salt contents in cheese whey.

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التوصيل الكهربي في اللبن الخام والجبن القريش

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أجريت هذه الدراسة لمعرفة العلاقة بين المكونات المختلفة للبن البقرى (من منطقة منقباد- بمحافظة أسيوط) و كذلك التركيب الكيماوي للجبن القريش (من منطقة درنكة – بمحافظة أسيوط) على التوصيل الكهربي له بالملليموز/ سم عند ٢٥ ⁰م , حيث تم تجميع ٤٢ عينة من اللبن الخام خلال الأشهر الباردة (ديسمبر، يناير، فبراير بمتوسط درجة حرارة ١٨±٢⁰م) والدافئة (مايو، يونيو، يوليو بمتوسط درجة حرارة ٣٧ ±٢⁰م) , ١٥ عينة من الجبن القريش من المناطق تحت الدارسة و كان متوسط قيمة التوصيل الكهربي خلال الأشهر الباردة أعلى من الدافئة حيث كان ٣,٥٩±٠,٤٧ , ٢,٤٩ ±٠,٣٩ , على التوالي.

ومن ناحية أخرى كان متوسط قيمة التوصيل الكهربي لعينات الجبن القريش المجمعة من منطقة درنكة– محافظة أسيوط ٥,٨٩ ± ٠,٢٤. كما ان ٤٧,٦٧ % من عينات الجبن القريش كانت تتراوح فيها قيمة التوصيل الكهربي من ٦-٨ ملليموز/ سم عند ٢٥ ⁰ .

وجد أن ١٩,١ % و ٩,٥٢٤ % ، ٤٦,٦٧% من عينات ألبان الأشهر الباردة و الدافئة، الجبن القريش تتراوح فيها قيمة التوصيل الكهربي من ٦ إلى ٨ ملليموز / سم عند ٢٥° م – مما يؤدى لتزايد احتمالات أصابتها بالتهاب الضرع . كما وجد أن تواجد الملح في شرش الجبن القريش أدي إلي زيادة حادة في التوصيل الكهربي. تقترح الدارسة انه يمكن التنبؤ بالإصابة بمرض التهاب الضرع بقياس التوصيل الكهربي للبن.

قام بتحكيم البحث

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