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Effect of Storage at Different Temperatures on Physical, Chemical and Microbiological Properties of Camel Milk Powder

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Abstract. Whole camel milk powder was manufactured using a single stage mobile spray drier. The milk powder was stored for 6 months at 7°C, 21°C and 37°C. Storage at 7°C had a very little effect on the properties of the milk powder, whereas storage at 21°C or 37°C led to a decrease in the moisture content up to the third month, then started to increase at the 6th month of storage. Both protein and fat contents decreased throughout storage, whereas there was a gradual increase in the non protein nitrogen. Acid degree value increased from 1.10 to 1.43 meq/100g fat and lipolysis from 0.142 to 0.62 meq free fatty acid/L after 6 months of storage at 37°C. The solubility index increased from 0.11 to 0.29 ml when milk powder stored at 37°C for 6 months. The total bacterial count of the camel milk powder was about 3.0 $\log_{10}$ cfu/g. This number decreased throughout the storage period. The loss was higher when milk powder stored at 37°C compared to 21°C. Whole milk powder was found to be suitable for reconstitution even after 6 months of storage at 37°C, on a basic of physical, chemical and microbiological properties.

Introduction

Camel milk plays an important role in the human diet in many parts of the world. It represents one of the most valuable food resources in arid and semiarid zones [1]. It has been reported that a normal camel on good feed can produce 2000 liters of milk per lactation period [2]. In Saudi Arabia, camel milk is consumed either fresh, pasteurized or in the form of a fermented milk product called "Ugt" [3].

Some attempts have been made to manufacture certain dairy products from camel milk such as cheese [4], ice cream [5] and acidophilus milk [6].

Although many papers have been published on the manufacture, microbiological quality, storage stability and sensory properties of cow milk powder [7-11], there is limited information on the manufacture of camel milk powder.

The present investigation was undertaken to study the possibility of manufacturing whole camel milk powder. The effect of 6 months storage at different temperatures on physical, chemical and microbiological properties were also studied. This evaluation could be used to assess the optimum storage conditions for whole camel milk powder.

Materials and Methods

Manufacture, packing and storage of whole camel milk powder

Fresh whole camel milk was obtained from Al-Faisalia farm, Riyadh, Saudi Arabia. The whole milk was pasteurized at 72°C for 15 sec. It was evaporated in a QVF teaching system evaporator (CTS4 climbing film and natural circulation evaporator - England). After passing through the vapor preheaters and being heated by a direct steam injection unit, the milk flowed through holding tubes and was then cooled by being released into a flash vessel. The milk was then concentrated to total solids of approximately 17%. The concentrated milk (60°C) was dried in a single stage mobile spray drier (Niro Atomizer, Denmark); the inlet air temperature was 195°C and the temperature of the air at the outlet of the dryer was 95°C.

The quality of camel milk powder was assessed by analysis of water content, total nitrogen and fat content according to the methods described by the American Public Health Association (APHA) [12]. For non-protein nitrogen (NPN) content determination, milk powder was reconstituted to 11% total solids. The sample was then treated as determining NPN in liquid milk [12]. NPN was calculated as for milk except that the value was multiplied by the appropriate dilution factor.

The pH was determined at 21°C using a digital pH meter (Corning pH meter 240).

Storage conditions

Milk powder was packed and sealed in polyethylene bags (200 gm). All bags were covered with aluminum foil, then stored at 7°C, 21°C and 37°C for 6 months. The keeping quality was assessed after 0, 1, 3 and 6 months of storage.

Microbiological analysis

The procedures described by the APHA [13] were followed in the preparation of culture media, diluents and chemical reagents, and for dilution and plating techniques. Total bacterial count, psychrotroph count, lipolytic count, proteolytic bacterial count, coliform count, yeast count and mold count were determined according to the method of APHA [12].

Biochemical tests

Preparation of samples for biochemical tests was accomplished by reconstituting the whole milk powder to 11% total solids.

A. Proteolysis

Samples were prepared for analysis by adding 10 ml of 0.75 N trichloroacetic acid and one ml of water to 5 ml of sample to give a final concentration of 0.47 N (7.7%) TCA. After 10 min of incubation at room temperature, the samples were filtered using Whatman No. 2 filter paper (Whatman corp., Clifton, NJ, U.S.A.). The concentration of free amino groups in the filtrate was determined using o-phthaldialdehyde reagent as described by Church *et al.* [14]. The standard curve was prepared using Leu-Gly (Sigma Chemical Co., St. Louis, Mo., U.S.A.).

B. Lipolysis

The acid degree value (ADV) of the prepared sample was determined according to the procedure described by Deeth and Fitz–Gerald [15]. ADV was expressed in meq/100g fat. Free fatty acids were determined according to the modified Copper Soap Solvent Method [16 p. 35].

C. Amino acid analysis

The amino acid content of the whole camel milk and the prepared sample was determined after hydrolysis with 6 N HCl for 24 h at 110°C [17]. The hydrolysate was analyzed on a Shimadzu LC – 10 AD amino acid analyzer (Kyoto, Japan).

Solubility index

The solubility index of the whole camel milk powder was assessed according to the procedure described by Niro Atomizer [18, p. 23]. Thirteen grams of whole milk powder was added to 100 ml of water at 24°C, then mixed for 90 sec. After 15 minutes, the mixture was filled into a centrifuge glass up to the 50ml mark. Then centrifuged for 5 minutes. All sediment free liquid was sucked up. The glass was filled with water up to the 50 ml mark, then centrifuged for 5 minutes.

Solubility index = ml of sediment in the centrifuge glass obtained from 50 ml of reconstituted milk.

Statistical analysis

The values reported in the results are the average of the values of three experiments. Analysis of variance (ANOVA) and the least significant differences (LSD) were done using the SAS statistical analysis system [19].

Results and Discussion

Chemical composition and microbiological quality of raw camel milk

The chemical composition of the whole raw camel milk used to manufacture the milk powder is shown in Table 1. The results obtained in this study are close to those obtained by other researchers who studied the chemical composition of camel milk [6, 20-23]. Total solids of camel milk were found to range between 9.4 and 14.4% [21]. This difference in camel milk composition reflects the difference in breed, state of lactation, sampling procedures and drinking water for the lactating animal. Available water for the animal was reported to be the most important factor, which affects the chemical composition of the camel milk [24].

Table 1. Chemical composition of camel milk used to manufacture the milk powder[a]

Component	%
Moisture	88.8
Fat	3.10
Total protein (N×6.38)	3.19
Non protein nitrogen	0.04
Ash	0.81
Acidity	0.15
PH	6.77

[a]Data are the average of three experiments

Table 2 represents the amino acid composition of the raw camel milk. The amino acid content is essentially compared to that obtained by Sawaya *et al.* [20] and Mehaia and AlKanhal [25]. The essential amino acid profile (Table 2) compared favorably with the amino acid requirements of the FAO/WHO/UNU for adults [26].

Table 2. Amino acid composition of camel milk (g/100g protein)

Amino acid	This study[a]	Sawaya *et. al.* [20]	Mehaia and AlKanhal [25]	FAO/WHO/UNU requirement for Adult [26]
Aspartic	6.36	7.6	6.43	
Threonine	4.04	5.2	4.25	0.9
Serine	4.84	5.8	4.20	
Glutamic	17.76	23.90	19.46	
Proline	10.43	11.10	11.12	
Glycine	1.26	1.70	1.31	
Alanine	2.27	2.80	2.67	
Valine	5.24	6.10	6.87	1.3
Methionine	2.30	2.50	3.56	1.7
Isoleucine	4.52	4.50	5.03	1.3
Leucine	9.42	10.40	9.53	1.9
Tyrosine	4.24	4.50	4.03	
Phenylalanine	4.23	4.60	5.57	1.9
Histidine	2.76	2.50	2.69	1.6
Lysine	6.81	7.0	7.08	1.6
Arginine	3.16	3.9	3.83	

[a]Data are the average of three experiments

The microbiological quality of the raw camel milk is shown in Table 3. Total bacterial count was 4.65 $\log_{10}$ cfu/ml. This figure is lower than that previously reported by Al-Mohizea [27] and Zahran and Al-Saleh [28]; their figures were 5.5 and 6.5 $\log_{10}$ cfu/ml, respectively. Coliform count was 2.4 $\log_{10}$ cfu/ml (Table 3), whereas Al-Mohizea [27] reported an average of 3.7 $\log_{10}$ cfu/ml. Proteolytic and lipolytic bacterial counts were 3.54 and 4.20 $\log_{10}$ cfu/ml, respectively, which represented 13% and 34% of the total count. Zahran and Al-Saleh [28] found that proteolytic bacterial count represented around 19% of the initial population of bacteria found in raw camel milk. The analyzed milk samples had no yeasts and mold. The microbial analysis indicates the good quality of the raw milk used to manufacture the milk powder.

Table 3. Mean counts of micro-organisms in raw camel milk used to manufacture milk powder[a]

Micro-organisms	Total counts ($\log_{10}$ cfu/ml)
Total bacteria	4.65
Psychrotrophic	4.10
Proteolytic	3.54
Lipolytic	4.20
Coliform	2.40
Yeasts & Molds	--

[a]Data are the average of three experiments

Chemical properties of the whole camel milk powder

The effect of storage on the chemical properties of the whole camel milk powder is shown in Table 4. Storage at 7°C had very little effect on the chemical properties of the milk. However, when milk was stored at 21°C or 37°C, there was a change in chemical properties. As expected changes at 37°C were higher than that occurred at 21°C. The moisture content decreased significantly ($P<0.05$) up to the third month of storage, then started to increase to almost the initial level after the sixth month of storage. Moisture content of the milk powder (Table 4) was lower than the maximum moisture content (3%) recommended for the whole milk powder suitable for reconstitution [29, p.40]. The change in the moisture content of the milk powder during storage was also noticed by Celestino *et al.* [9]. This change probably related to the change of lactose from amorphous to α-hydrate crystalline state [30, p.289].

Table 4 shows that the fat content decreased throughout the storage period either at 21°C or 37°C, and the decrease was significant ($P<0.05$) after 3 and 6 months of storage. This may be due to the action of the heat stable lipases secreted by lipolytic bacteria. Celestino *et al.* [9] reported lipolytic activity during storage of whole milk powder at 25°C for 8 months. The total protein content also decreased throughout the storage period (Table 4). The decrease was significant ($P<0.05$) after 6 months of storage at 7°C and 21°C, and after 3 months at 37°C. There was a gradual increase in the non protein nitrogen. This increase was significant ($P<0.05$) after 6 months at 21°C and after one month of storage at 37°C. This proteolysis is mainly due to the heat stable proteinases secreted by proteolytic bacteria. Ipsen and Hansen [31] reported that the proteolysis in dried whole milk may be due to the heat stable proteinases which remain active after spray drying.

Table 4. Chemical properties of whole camel milk powder stored for 6 months at different temperature[a]

Chemical attribute	Storage time (month) at 7°C				Storage time (month) at 21°C				Storage time (month) at 37°C			
	0	1	3	6	0	1	3	6	0	1	3	6
Moisture %	1.95	1.95	1.93	1.93	1.95	1.92	1.87	1.92	1.95	1.90	1.81	1.97
Fat %	27.54	27.50	27.3	27.2	27.54	27.1	26.8	26.30	27.54	27.0	26.3	26.0
Total protein % (TP)	28.10	28.10	27.9	27.3	28.10	28.0	27.5	27.10	28.10	27.6	27.1	26.3
Non protein nitrogen (NPN) %	0.35	0.35	0.37	0.37	0.35	0.38	0.40	0.47	0.35	0.41	0.45	0.49
pH	6.70	6.70	6.70	6.70	6.70	6.70	6.68	6.67	6.70	6.70	6.67	6.66

[a]Data are the average of three experiments.
(LSD: moisture 0.10; fat 0.76; TP 0.65; NPN 0.06; pH 0.03).

The pH of the milk powder slightly changed during storage. After 6 months of storage at 37°C, the pH value decreased from 6.70 to 6.66. This change in the pH is probably due to release of free fatty acids as a result of the lipolytic activity.

Biochemical properties

When camel milk powder was stored at 7°C (data not shown) there was no detectable change in its biochemical properties, however, on keeping the milk at 21°C or 37°C, there was some change in the biochemical properties (Table 5).

Table 5. Biochemical properties of whole camel milk powder stored for 6 months at 21°C and 37°C[a]

Biochemical attribute	Storage time (month) at 21°C				Storage time (month) at 37°C			
	0	1	3	6	0	1	3	6
Proteolysis[b]	2.77	2.78	2.79	2.79	2.77	2.81	2.90	2.92
Lipolysis[c]	0.142	0.310	0.510	0.55	0.142	0.420	0.63	0.62
Acid degree value[d]	1.10	1.20	1.30	1.35	1.10	1.23	1.38	1.43

[a]Data are the average of three experiments
b: free amino groups (μM)
c: meq free fatty acid/L
d: meq/100gfat
(LSD: proteolysis 0.07; lipolysis 0.05; ADV 0.08)

Proteolysis

Proteinase activity did not change significantly ($P<0.05$) throughout the storage period at 21°C (Table 5), whereas at 37°C there was significant ($P<0.05$) increase in proteinase activity after storage for 3 months at 37°C. This is supported by the analysis of total protein and non-protein nitrogen (NPN) (Table 4). Celestino *et al.* [9] reported that proteinases retained their activity during storage of cow milk powder and they attributed that to the low water activity (a_w) of the milk powder. In addition, proteinases in milk powder may not be completely inactivated during processing [32].

Lipolysis

There was significant ($P<0.05$) increase in lipolytic activity of the stored camel milk powder during storage at 21°C and 37°C after one month of storage (Table 5). Lipolysis was increased from 0.142 to 0.62 meq free fatty acid/L, after 6 months of storage at 37°C. The increase in the lipolysis activity throughout the storage period was probably due to the heat stable lipases secreted by lipolytic bacteria found in the raw milk. In this study lipase producing bacteria represented 34% of the total bacterial count in raw milk.

Acid degree value (ADV)

Acid degree value of camel milk powder has increased. The increase was significant ($P<0.05$) at 21°C and 37°C after the first month of storage and up to 1.43 after 6 months of storage at 37°C (Table 5). A comparison between ADV and lipolysis shows that the change in lipolytic activity throughout storage was higher than that of ADV. ADV determines only some medium chain fatty acids (C10-C16) and not short chain fatty acids (C4-C8) [33]. Celestino *et al.* [9] reported an increase in both free fatty acids (FFA) and acid degree value (ADV) during storage of raw cow milk up to 8 months. Although milk powder has a very low a_w, lipolysis took place at a constant level in full cream milk powder. Another explanation for lipase activity at low a_w values was reported by Anderson [34], who stated that lipolysis occurs at low a_w because substrates for lipase are water insoluble and the water phase is not the only location for the reactions catalyzed by the enzymes.

Solubility index

The solubility index of the milk powder is shown in Table 6. Storage of the milk powder at 37°C for 6 months increased the solubility index significantly ($P<0.05$) from 0.11 to 0.29 ml. The increase in solubility index was higher at 37°C compared to that at 7°C and 21°C, this is probably due to the formation of insoluble material. This figure is still lower than the maximum official standard specification of 0.5 ml [35 p. 104]. Kudo *et al.* [36] mentioned some factors, which contribute to the increase in the solubility index of whole milk powder during storage; such as storage temperature of the milk powder, crystallization of lactose and non-enzymatic browning. The mechanism of the formation of insoluble material during storage of milk powder is not fully understood [36].

Table 6. Solubility index of the whole milk powder stored for 6 months at different temperature[a]

Storage period (month)	Solubility index (ml)		
	7°C	21°C	37°C
0	0.11	0.11	0.11
1	0.11	0.13	0.17
3	0.13	0.16	0.19
6	0.13	0.21	0.29

[a]Data are the average of three experiments
(LSD: 0.09)

Microbiological tests

Table 7 shows the bacterial content of the camel milk powder stored at 21°C and 37°C for 6 months. The total bacterial count (TBC) of the milk powder manufactured in this study was about 3.0 $\log_{10}$ cfu/gm, which is in the range recommended for the

microbiological standard of whole milk powder for reconstitution [35, p.113], and lower than that mentioned by Sanderson [29]. The low bacterial count found in the camel milk powder was probably due to the good quality of the raw camel milk (Table 3). Lovell [37, p.245] reported that raw milk counts in excess of 10^5 cfu/ml probably lead to more than 10^4 cfu/g in the dried product. However, Celestino *et al.* [9] used raw milk with a total bacterial count over 10^5 cfu/ml, and obtained milk powder which had TBC of $<10^4$ cfu/g. They attributed the difference between bacterial count in raw milk and the manufactured milk powder to the type of bacteria, especially the heat resistant spore forming bacteria.

The bacterial count decreased significantly ($P<0.05$) throughout the storage period (Table 7). There was no change in the number of bacteria when milk powder was stored at 7°C (data not shown). This reduction in the number of bacteria throughout storage is probably due to the low a_w of the milk powder. Bacteria usually require available moisture to grow, they cannot grow if the environment supplies a_w below 0.91.

Table 7. Mean bacterial counts (converted to logarithms base 10) in whole camel milk powder stored at 21°C and 37°C[a]

Bacterial tests	Storage period (months) at 21°C				Storage period (months) at 37°C			
	0	1	3	6	0	1	3	6
Total count (TC)	3.0	2.9	2.85	2.80	3.0	2.80	2.73	2.70
Psychrotrophic (Psy)	2.77	2.6	2.54	2.54	2.77	2.55	2.50	2.50
Proteolytic	2.0	2.0	1.80	1.80	2.0	2.0	1.73	1.71
Lipolytic	2.6	2.52	2.52	2.4	2.6	2.55	2.50	2.2

[a]Data are the average of three experiments
(LSD: TC 0.14; psy 0.15; proteolytic 0.20; lipolytic 0.26)

The decrease in bacterial population was higher when milk powder was stored at 37°C compared to storage at 21°C. This is probably due to the high rate of accumulation of fatty acids resulted from fat oxidation at 37°C. The formation of short chain fatty acids may affect the growth rate of different types of bacteria. This result is in good agreement with that obtained by Celestino *et al.* [9] and Renner [32] who found that the number of bacteria decreased throughout the storage of milk powder.

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تأثير التخزين على درجات حرارة مختلفة فى الصفات الطبيعية والكيميائية والميكروبية لحليب الإبل المجفف

عبدالرحمن بن عبدالله الصالح

قسم علوم الأغذية والتغذية ، كلية الزراعة ، جامعة الملك سعود ، الرياض ، المملكة العربية السعودية

(قدم للنشر في ١٤٢٠/١٠/٧هـ؛وقبل للنشر في ١٤٢١/١/٧هـ)

ملخص البحث: تم تصنيع حليب إبل جاف كامل الدسم باستخدام طريقة الرذاذ. خزن الحليب الجاف الناتج على درجات حرارة ٧°م ، ٢١°م ، ٣٧°م لمدة ستة أشهر. أوضحت الدراسة أن التخزين على درجة حرارة ٧°م كان له تأثير بسيط على صفات الحليب الناتج. بينما التخزين على درجات ٢١°م أو ٣٧°م أدى إلى نقص في الرطوبة حتى الشهر الثالث ، ثم بدأت الرطوبة بالزيادة خلال التخزين وحتى الشهر السادس. وقد حدث نقص لكل من البروتين والدهن خلال فترة التخزين ، بينما محتوى النيتروجين غير البروتيني زاد تدريجياً خلال فترة التخزين. بالإضافة إلى ذلك فإن قيمة رقم الحموضة زادت من ١.١٠ إلى ١.٤٣ مل مكافئ/١٠٠ جم دهن كذلك تحلل الدهون زاد من ٠.١٤٢ إلى ٠.٦٢ مل مكافئ أحماض دهنية حرة/لتر بعد ٦ أشهر من التخزين على ٣٧°م. زاد معامل الذوبان خلال فترة التخزين لمدة ٦ شهور على درجة ٣٧°م من ٠.١١ إلى ٠.٢٩ مل. كان المحتوى البكتيري للحليب الجاف المصنع حوالي ٣لـو١٠ وحدة تكوين مستعمرة/جرام ، وتناقص هذا العدد خلال فترة التخزين وكان النقص على درجة ٣٧°م أعلى بالمقارنة بدرجة ٢١°م. بناءً على الصفات الطبيعية والكيميائية والبكتريولوجية للحليب الجاف بعد فترة التخزين يعتبر الحليب الجاف المصنع صالحاً لاسترجاعه حتى وبعد تخزينه لمدة ٦ أشهر على درجة ٣٧°م.