

Storage Studies on Spray Dried Camel Milk Powder



**THESIS SUBMITTED TO THE
ICAR-NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
AWARD OF
THE DEGREE OF
MASTER'S IN FOOD TECHNOLOGY
BY
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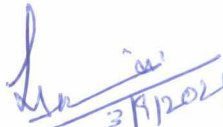
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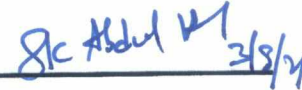

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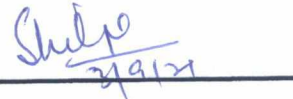
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This is to certify that the thesis entitled “**Storage Studies on Spray Dried Camel Milk Powder**” submitted by **Miss. Akanksha Joshi** towards the partial fulfilment of the requirement for the award of the degree of **Master of Science in Food Technology** of the **ICAR-National Dairy Research Institute (Deemed University), Karnal (Haryana), India**, is a bonafide research work carried out by her under my supervision and no part of the thesis has been submitted for any other degree or diploma.

Date: July 15, 2021


15/7/2021
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Abbreviations

i.e.	That is
viz.	Namely
Kg	Kilogram
Vit.	Vitamin
β	Beta
h	Hour
e.g.	Example
RH	Relative Humidity
κ	Kappa
IgA	Immunoglobulin A
IgM	Immunoglobulin M
IgG	Immunoglobulin G
g/l	Gram per litre
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FSSAI	Food Safety and Standards Authority of India
GlyCAM-1	Glycosylation-dependent cell adhesion molecule-1
Var.	Variety
I.U.	International Unit
mg/kg	Milligram per kilogram
hepG2	Human liver cancer cell line
GSH	Glutathione
<i>L. lactis</i>	<i>Lactobacillus lactis</i>
kPa	Kilo pascal
a_w	Water activity
L*	Lightness
a*	Redness/greenness
b*	Yellowness/blueness
μm	Micrometer
Nm	Nanometer
M₀	Monolayer moisture content
EMC	Equilibrium moisture content
BET	Brunauer-Emett-Teller

C	Energy Constant related to net heat of sorption
K	Adsorption Constant
R²	Coefficient of Determination
GAB	Guggenheim-Anderson-deBoer
PV	Peroxide value
cfu	Colony forming unit
d.b.	Dry basis
meq	Milliequivalents

ABSTRACT

The demand for camel milk is rising throughout the world due to its therapeutic properties, though its availability only in certain pockets is a major detriment to this. Drying has been used to increase the shelf life of the milk and its easy transportation. Several attempts have been made at freeze drying and spray drying of camel milk. Spray drying is preferred, as it is cost-effective. Earlier studies at our Institute optimized the process variables for spray drying of camel milk. The current research aims to determine the storage stability of the developed spray dried camel milk powder at different temperatures. Spray dried camel milk powder of composition ($1.42 \pm 0.17\%$ moisture, $26.80 \pm 0.52\%$ protein, $27.86 \pm 0.14\%$ fat, ash $8.04 \pm 0.10\%$, and $35.84 \pm 0.40\%$ lactose) was packed in single layered aluminium pouches and stored at 25, 37 and 45 °C. The moisture sorption isotherm was determined and monolayer moisture content was calculated using BET and GAB models at different temperatures. The results indicated that the equilibrium moisture content increased with water activity but reduced with increase in storage temperature. Monolayer moisture content also decreased from 3.17% (25 °C) to 2.60% (37 °C) and 1.63% (45 °C) by BET model. During the storage of 120 days, the highest reduction in most of the reconstititional properties (i.e., wettability, dispersibility, solubility) was observed in the powder stored at 45 °C. The moisture content increased significantly ($P < 0.05$) to $2.95 \pm 0.21\%$, $2.67 \pm 0.07\%$ and $2.39 \pm 0.34\%$ at 25, 37 and 45 °C, respectively. Dispersibility of the powder reduced significantly ($P < 0.05$) from $67.83 \pm 0.44\%$ at zero day to 54.81 ± 1.28 , 50.95 ± 0.84 , $50.27 \pm 1.77\%$ at 25, 37 and 45 °C, respectively. Wettability of the powder sample at zero day was 3.67 ± 0.15 sec at $60 \pm 2^\circ\text{C}$ water temperature and increased significantly ($P < 0.05$) to 10.33 ± 0.33 , 13.17 ± 0.44 and 18 ± 1.15 sec with the temperature of storage. The initial solubility ($98.58 \pm 0.13\%$), reduced significantly ($P < 0.05$) to $87.35 \pm 0.36\%$, $89.56 \pm 0.92\%$ and $79.25 \pm 0.40\%$ at 25, 37 and 45 °C, respectively. The zero day microbial counts (total plate count - 2.18 ± 0.06 log cfu/g, thermophilic spore count - 1.13 ± 0.01 log cfu/g) increased significantly ($P < 0.05$) to 3.19 ± 0.04 , 3.10 ± 0.03 , 3.07 ± 0.03 log cfu/g and 1.15 ± 0.01 , 1.47 ± 0.01 , 1.91 ± 0.03 log cfu/g at 25, 37 and 45 °C, respectively. Coliform, yeast and mold counts also followed this increasing trend during storage. Physical properties like bulk density and flowability decreased on increasing storage temperature. Carr Index and Hausner ratio increased significantly ($P < 0.05$) to 14.96 ± 0.96 , 13.77 ± 0.73 and 16.91 ± 0.24 , and 1.18 ± 0.01 , 1.16 ± 0.01 and 1.21 ± 0.00 at 25, 37 and 45 °C, respectively. It was evident that most deterioration of powder occurred at 45 °C. Lower storage temperature resulted in increased moisture content and water activity, resulting in reduced flowability and increase in number of total plate counts. Major changes in the reconstititional properties took place due to absorption of moisture at low storage temperature and chemical changes due to melting of fat or state transition of amorphous lactose at higher storage temperature. At all the temperatures, spray dried camel milk powder was found to be stable and safe for human consumption till 120 days of storage. The storage temperature of 25 °C was recommended for spray dried camel milk powder, provided the packaging material used has lower water vapour transmission rate.

सार

ऊंट के दूध की मांग इसके चिकित्सीय गुणों के कारण दुनिया भर में बढ़ रही है, हालाँकि केवल कुछ खास इलाकों में ही उत्पादन इसकी उपलब्धता में एक बड़ी बाधा है। सुखाने का उपयोग दूध के शेल्फ लाइफ और इसके आसान परिवहन को बढ़ाने के लिए किया गया है। ऊंट के दूध को फ्रीज और स्प्रे ड्राई से सुखाने के कई प्रयास किए गए हैं। स्प्रे ड्राईंग को प्राथमिकता दी जाती है, क्योंकि यह लागत प्रभावी है। हमारे संस्थान में पहले के अध्ययनों ने ऊंट के दूध के स्प्रे ड्राईंग के लिए प्रक्रिया चर को अनुकूलित किया। वर्तमान शोध का उद्देश्य विभिन्न तापमानों पर विकसित स्प्रे ड्राई ऊंटनी के दूध पाउडर की भंडारण स्थिरता का निर्धारण करना है। सूखे ऊंट दूध पाउडर ($1.42 \pm 0.17\%$ नमी, $26.80 \pm 0.52\%$ प्रोटीन, $27.86 \pm 0.14\%$ वसा, राख $8.04 \pm 0.10\%$, और $35.84 \pm 0.40\%$ लैक्टोज) को एकल स्तरित एल्यूमीनियम पाउच में पैक किया गया था और 25, 37 और 45 डिग्री सेल्सियस पर संग्रहीत किया गया था। नमी सोखने वाला आइज़ोथर्म निर्धारित किया गया था और विभिन्न तापमानों पर बेट और गैब मॉडल का उपयोग करके मोनोलेयर नमी सामग्री की गणना की गई थी। परिणामों ने संकेत दिया कि संतुलन नमी की मात्रा पानी की गतिविधि के साथ बढ़ी लेकिन भंडारण तापमान में वृद्धि के साथ कम हो गई। मोनोलेयर नमी की मात्रा भी बेट मॉडल द्वारा 3.17% (25°C) से घटकर 2.60% (37°C) और 1.63% (45°C) हो गई। 120 दिनों के भंडारण के दौरान, अधिकांश पुनर्गठन गुणों (यानी, गीलापन, फैलाव, घुलनशीलता) में सबसे अधिक कमी 45 डिग्री सेल्सियस पर संग्रहीत पाउडर में देखी गई थी। नमी की मात्रा में उल्लेखनीय रूप ($P < 0.05$) से वृद्धि हुई $1.42 \pm 0.17\%$ से $2.95 \pm 0.21\%$, $2.67 \pm 0.07\%$ और $2.39 \pm 0.34\%$ क्रमशः 25, 37 और 45 डिग्री सेल्सियस पर बढ़ गई। पाउडर की फैलावता शून्य दिन पर $67.83 \pm 0.44\%$ से 54.81 ± 1.28 , 50.95 ± 0.84 , $50.27 \pm 1.77\%$ क्रमशः 25, 37 और 45 C पर काफी कम हो गई ($P < 0.05$)। शून्य दिन पर पाउडर के नमूने की वेटेबिलिटी 3.67 ± 0.15 सेकंड $60 \pm 2^\circ\text{C}$ पानी के तापमान पर थी और भंडारण के तापमान के साथ 10.33 ± 0.33 , 13.17 ± 0.44 और 18 ± 1.15 सेकंड में काफी ($P < 0.05$) बढ़ गई। प्रारंभिक घुलनशीलता ($98.58 \pm 0.13\%$), क्रमशः ($P < 0.05$) से $87.35 \pm 0.36\%$, $89.56 \pm 0.92\%$ और $79.25 \pm 0.40\%$ 25, 37 और 45 डिग्री सेल्सियस पर क्रमशः कम हो गई। माइक्रोबियल काउंट्स जीरो डे (कुल प्लेट काउंट – 2.18 ± 0.06 लॉग सीएफयू/ग्राम, थर्मोफिलिक स्पोर काउंट – 1.13 ± 0.01 लॉग सीएफयू/ग्राम) ($P < 0.05$) से बढ़कर 3.19 ± 0.04 , 3.10 ± 0.03 , 3.07 ± 0.03 लॉग सीएफयू/ग्राम और 1.15 ± 0.01 , 1.47 ± 0.01 , 1.91 ± 0.03 लॉग सीएफयू/ग्राम क्रमशः 25, 37 और 45°C पर पाए गए। भंडारण के दौरान इस बढ़ती प्रवृत्ति का पालन कोलीफॉर्म, यीस्ट और मोल्ड काउंट्स ने भी किया। भंडारण तापमान बढ़ने पर थोक घनत्व और प्रवाह क्षमता जैसे भौतिक गुणों में कमी आई। कार इंडेक्स और हॉसनर अनुपात क्रमशः ($P < 0.05$) से 14.96 ± 0.96 , 13.77 ± 0.73 और 16.91 ± 0.24 , और 1.18 ± 0.01 , 1.16 ± 0.01 और 1.21 ± 0.00 25, 37 और 45 डिग्री सेल्सियस पर बढ़ गया। यह स्पष्ट था कि पाउडर की सबसे अधिक गिरावट 45°C पर हुई। कम भंडारण तापमान के परिणामस्वरूप नमी की मात्रा और पानी की गतिविधि में वृद्धि हुई, जिसके परिणामस्वरूप प्रवाह क्षमता कम हो गई और प्लेट की कुल संख्या में वृद्धि हुई। कम भंडारण तापमान पर नमी के अवशोषण और वसा के पिघलने या उच्च भंडारण तापमान पर अनाकार लैक्टोज के राज्य संक्रमण के कारण रासायनिक परिवर्तनों के कारण पुनर्गठन गुणों में बड़े बदलाव हुए। सभी तापमानों पर, स्प्रे ड्राई ऊंटनी के दूध के पाउडर को 120 दिनों के भंडारण तक स्थिर और मानव उपभोग के लिए सुरक्षित पाया गया।

1. INTRODUCTION

Camels are the members of the Camelidae family, consisting of two major types i.e., small and large camels. These are further subdivided into *Camelus*, *Vicugna* and *Lama* genera. The genus *Camelus* has two different species: *Camelus bactrianus*, the two-humped camel, producing 5 litres of milk per day, and *Camelus dromedarius*, the one humped camel breed, producing 20 litres of milk per day. Bactrian camels are found in cold regions of central Asia. The dromedary camels are indigenous to India and is shown to have good genetic potential to produce milk. The global camel population, across 47 countries, is estimated to be about 26.99 million. Eastern and Northern Africa has about 83% of the camel population and rest of the camels inhabit the Indian subcontinent and Middle East. Somalia, having highest population, contributes to about 7.10 million. India has tenth ranking in the world with 0.38 million camels (FAOSTAT, 2015). In India, camel milk is used majorly in south-eastern districts of Rajasthan and adjacent Madhya Pradesh. Seventy per cent of the camel population of India is found in Rajasthan. Out of the four major breeds of camel in India, viz. Bikaneri, Jaisalmeri, Kutchi and Mewari, the most prevalent in these regions is the Mewari breed. Genomic study on camel family revealed that they contain adapted and evolved genes for desert adaptation such as osmoregulation, fat metabolism, heat stress response, ultraviolet radiation, and choking dust (Wu *et al.*, 2014). There is a continuous decline in the camel population, due to its traditional use and various ailments. In desert areas, camel milk is important in daily life as a source of food and used as medicine for various ailments. Camel can produce milk in harsh environment and has advantage of longer lactation period. It is cost-effective in terms of feed conversion.

The total camel milk production worldwide in 2018 was 31.371 million tones, out of which 7.959 million tones was solely contributed by India with an average annual productivity of 179.5 kg per year (FAOSTAT, 2019). Camel milk is generally opaque white in colour, and has faint sweetish odor and sharp taste. It has high content of vitamin C, Fe, K, insulin, and low fat with higher content of unsaturated and long chain fatty acids and lactose. Camel milk contains high level of proteins and other organic compounds, some of which have antimicrobial abilities. Due to the absence of β -lactoglobulin, it is closer to human milk. The shelf life of fresh camel milk is 8-9 h, which can be further extended upto 18-20 h through activation of the lactoperoxidase system (Singh *et al.*, 2017). Food Safety and Standards Authority of India (FSSAI, 2016) has set the respective minimum legal requirements for fat and solids not fat in camel milk as 2% and 6%.

Camel milk sours slowly and can be kept longer than cow milk at the refrigeration temperature. Camel produces diluted milk in hot weather due to scarcity of water. Camel milk is gaining importance due to its medicinal properties. It has protective action against many diseases like diabetes, autism, diarrhea, hepatitis and alcohol induced liver damage. Its benefits can be attributed to the presence of many immunologically important molecules such as lysozymes, lactoferrin and lactoperoxidase. It contains extraordinarily high levels of insulin-like molecule. It is claimed that processing of camel milk into products is difficult, though in the recent years it has been successfully processed into a variety of products, including soft cheese, fermented milk, yoghurt and butter (Berhe *et al.*, 2017).

There is a limited availability of camel milk as they are typically raised in arid places like deserts. So, there is also difficulty in transportation to other places while maintaining its physiochemical and nutritional properties. Therefore, there is a high need to convert it into products with enhanced storage stability, (e.g., powder) in order to increase its shelf life, extend its applications in various products and to make it available globally. Additionally, powder requires low storage capacity and transportation cost. Camel milk can be converted into powder form by freeze and spray drying. Freeze drying is more common and has been commercialized worldwide. The major brands in India are Aadvik Foods®, Amul®, DNS Global Foods™. During drying, protein, fat, lactose, minerals are transported at the powder's surface, showing different concentrations. Freeze drying of the camel milk does not affect its chemical composition, i.e. vitamins, minerals, amino acids and fatty acids of camel milk (Ibrahim and Khalifa, 2015), but it is very costly as it involves high throughput equipment/machinery. To reduce the processing cost, there was a need for other techniques. Spray drying is one such technique that can be used for producing powders from milk and milk products. When atomized milk droplets come in contact with hot air in the drying chamber of the spray dryer, they instantly give up moisture. It is a continuous operation, can handle a variety of feeds and is economic. It is the most used commercial technique for drying milk, due to the very short time of heat contact and high rate of evaporation, giving a high-quality product with relatively low cost. Moreover, a consistent particle size distribution is another reason for spray drying of some industrial products. But, due to poor heat stability of camel milk and loss of nutrients, the process has not become largely popular. Spray drying causes significant loss of calcium and iron in powders (Deshwal *et al.*, 2020). The process is characterized by factors such as inlet and outlet temperature, feed rate, atomizer speed, product

temperature and thermal and evaporative efficiencies (Perez and Flores, 1997). Physiological properties of the camel milk powder (water activity, powder colour, flowability, solubility, yield) produced by spray drying are greatly affected by direction of feed.

Due to similarities in the composition of cow and camel milk (carbohydrates, protein and fat), changes in properties of camel milk powder could be similar to that of cow milk powder, during storage. The particles of powder produced by spray drying are constructed of continuous mass of amorphous lactose and other low molecular weight components in which protein molecules and fat globules are embedded (Walstra *et al.*, 2005).

When stored in the appropriate storage conditions, whole milk powder has a shelf life of 12 months and skim milk powder in excess of 2 years. Generally, the shelf life is established for ensuring microbiological safety and acceptability of sensory attributes like colour and flavour. Quality of the milk powder does not remain same during storage, often exhibiting problems such as caking. If surrounding relative humidity (RH) is high, moisture content of powder reduces. This is due to difference in water sorption by crystalline and amorphous lactose. But at high RH, more α -monohydrate crystals will be formed. It leads to increase in water activity and deteriorative changes like browning and oxidation reactions. Fat oxidation requires the presence of O₂ and is enhanced by decreasing water activity, while other deteriorating changes like structural transformation, non-enzymatic browning and loss of lysine increases sharply with the increase in water activity (Roos, 2002). Due to these physiochemical changes, functional and reconstititional properties such as flowability, solubility, emulsifying and foaming properties also change during storage. The extent of changes that occur depends on the storage conditions such as RH, temperature at which it is stored and the time of storage. Therefore, study on the physiochemical changes that occur under storage conditions would be useful to predict the behaviour of camel milk powder during its end use. Consequently, the knowledge of moisture sorption isotherm is also mandatory to control the physical stability of dairy powders during storage. Bharati (2020) standardized the technology for camel milk powder at the Dairy Technology Division of ICAR-National Dairy Research Institute, Karnal. In order to conduct storage studies on the developed product, the present project was formulated with the following objective:

To study the effect of storage on physiochemical, reconstititional and functional properties of camel milk powder.

2. REVIEW OF LITERATURE

2.1 INTRODUCTION

Camel is known as the “ship of the desert” as it is the only means of transportation found in the desert areas. The body of a camel has been modified to conserve water, so they can survive in the hot and dry conditions of the desert. The worldwide camel population is approximately 35 million heads (FAOSTAT, 2019). Somalia, Sudan, Niger, Kenya, Chad, Ethiopia, Mali, Mauritania, and Pakistan constitute most of the camel population. In India, camels are mostly found in Rajasthan, followed by Gujarat, Haryana and Uttar Pradesh (Statista, 2021) As per the 2019 livestock census, India’s camel population halved to 2.5 lakh in 2019 from 5.2 lakh in 2007 (BAHS, 2019). The major camel breed in India are Bikaneri, Jaisalmeri, Kachhchi and Mewari. They have been shown to produce 3105–4190 kg milk per lactation at the rate varying from 3.8 to 10.8 kg/day (Singh *et al.*, 2017). The period of lactation can last up to 14-16 months. Milk yield depends upon various factors like breed, method of milking and month of lactation. India has average annual productivity of 179.5 kg per year (FAOSTAT, 2019).

2.2 CAMEL MILK

It is termed as ‘white gold of the dessert’ and is similar to human milk in composition. It lacks in β -lactoglobulin, contains double the amount of β -casein and has much higher immunoglobulins than cow milk. It is different from other ruminants’ milk as it contains less lactose and fat, high minerals, vitamin C and high insulin levels. Fat mostly consists of polyunsaturated fatty acids, which reduces serum level of lipids and hence prevalence of cardio-vascular diseases. It contains many protective proteins like lactoferrin, lactoperoxidase, lysozyme and immunoglobulins.

2.2.1 Physical Properties

Camel milk is generally opaque white in colour with a faint sweetish odour and sharp taste, sometimes salty. The opaque white colour is due to the presence of finely homogenized fat globules throughout the milk. The change observed in the taste depends on type of fodder and availability of water to drink. Density varies from 1.026-1.035 and pH from 6.2-6.5, which are lower than that of cow’s milk (Kula and Tegegne, 2016).

2.2.2 Chemical Composition

Composition of camel milk varies with geographical origin, physiological stage, feeding condition, seasonal or genetic or health status of camel (Table 2.1).

Table 2.1. Chemical composition of whole and skim camel milk

Parameters	Whole camel milk	Skim camel milk
Fat (g/100g)	2.99 ± 0.09	0.10 ± 0.00
SNF (g/100g)	7.71 ± 0.21	7.86 ± 0.21
Total solids (g/100g)	10.73 ± 0.18	7.96 ± 0.21
Protein (g/100g)	2.67 ± 0.14	2.67 ± 0.07
Lactose (g/100g)	4.16 ± 0.10	4.32 ± 0.12
Ash (g/100g)	0.88 ± 0.03	0.87 ± 0.02
Acidity (g/100g lactic acid)	0.17 ± 0.01	0.18 ± 0.00

Source: Deshwal *et al.* (2020)

2.2.2.1 Proteins

The major protein in camel milk is casein and constitutes about 52-87% of the total proteins. β -casein and α -casein constitutes 65 and 21% of the whole casein, respectively. κ -casein content of camel milk is about 3.47%. Major whey proteins in milk of mammals are β -lactoglobulin (β -LG), α -lactalbumin (α -LA), serum albumin (SA), lactoferrin, and different immunoglobulins (Ig). β -lactoglobulin is absent in camel milk, while α -lactalbumin and serum albumin are present in higher amount. Whey to casein protein ratio is higher in camel milk in comparison with cow milk, resulting in formation of soft curd. Composition of various casein and whey proteins in is as shown in Table 2.2 and Table 2.3 respectively.

Table 2.2. Composition of casein in camel, bovine and human milk

Protein	Camel (g/l)	Bovine (g/l)	Human (g/l)
α_{s1} -casein	5.3 (22%)	9.5 (38%)	0.43 (12%)
α_{s2} -casein	2.3 (9.6%)	2.5 (10%)	None†
β -casein	15.6 (65%)	9.8 (39%)	2.4 (65%)
κ -casein	0.8 (3.3%)	3.3 (13%)	0.87 (24%)
Total casein	24.0	25.1	3.7

†Corresponding coding sequence absent in genome.

Source: Hailu *et al.* (2016)

Table 2.3. Composition of whey protein in camel, bovine and human milk

Protein	Camel (g/l)	Bovine (g/l)	Human (g/l)
β -lactoglobulin	None†	3.1 (53.6%)	None
α -lactalbumin	2.3 (27%)	1.1 (20.1%)	3.2 (42%)
Serum albumin	2.2 (26%)	0.35 (6.2%)	0.57 (7.5%)
Immunoglobulins IgA, IgG, IgM	1.5 (18%)	0.20 (3.5%)	1.4 (18%)
GlyCAM-1	0.95 (11%)	0.30 (5.3%)	Not detectable
Whey acidic protein	0.16 (1.8%)	None†	None†
Peptidoglycan recognition protein Var.S	0.11 (1.3%)	Only mastitis	Not detectable
Lacto(trans)ferrin‡	0.095 (1.1%)	0.10 (1.8%)	2.3 (30%)
Lactoperoxidase	no data	0.03 (0.5%)	0.004 (0.1%)
Lysozyme C	0.00015	0.00007	0.13 (1.7%)
Total whey protein	8.5	5.7	7.6

†Corresponding coding sequence absent in genome; ‡Strong correlation with daily milk yield, somatic cell count, and stage of lactation; Mid-lactation values of pooled samples from mastitis-free milk.

Source: Hailu *et al.* (2016)

2.2.2.2 Fat

Fat content of camel milk depends upon stage of lactation, level of nutrition, breed, season, etc. It varies between 1.2 and 5.4% with average value of 3.29% as shown in the Table 2.4. Camel milk has fat globules which are smaller in size but has highest digestibility compared to buffalo, cow and goat milk. The fat globule in camel milk is naturally homogenized, and their size is smaller than the buffalo milk. It has been reported that the fat globule of camel milk remains attached to the protein, and that's why its fat is difficult to eliminate. It has lower amount of carotene as compared to cow milk, with similar cholesterol/fat ratio. Camel milk has higher amount of unsaturated as well as long chain fatty acids and low amount of short chain fatty acids (Table 2.4). Long chain poly-unsaturated fatty acids reduce the serum lipids and hence decrease the prevalence of cardiovascular diseases (Singh *et al.*, 2017).

Table 2.4. Fatty acids concentration (g %) of camel milk

Fatty Acid		Concentration (g %)			
Common name	Formula				
Butyric	C 4:0	0.66	3.5	1.0	0.048
Caproic	C 6:0	0.33	2.1	-	0.229
Caprylic	C 8:0	0.23	1.4	0.5	0.166
Capric	C 10:0	0.90	2.1	0.1	0.110
Lauric	C 12:0	0.79	3.1	0.5	0.060
Myristic	C 14:0	12.5	10.0	10.0	0.206
Myristoleic	C 14:1	1.1	1.70	1.5	0.066
Palmitic	C 16:0	31.5	26.60	31.5	0.529
Palmitoleic	C 16:1	9.4	1.70	9.0	0.403
Stearic	C 18:0	12.50	7.86	14.0	0.151
Oleic	C 18:1n9	19.1	29.0	25.0	0.495
Linoleic	C 18:2n6c	3.4	3.2	3.0	0.047
Arachidic	C 20:0	1.003	0.11	0.50	0.067

Source: Singh *et al.* (2017)

2.2.2.3 Lactose

Lactose content of camel milk depends on breed, stage of lactation, and state of hydration. Average lactose content is 49.8 g/l for camel milk, compared to 42 g/l for cow milk and 17 g/l for goat milk (Bouhaddaoui et al., 2019). Extensive variation in lactose content, usually ranging from 3.3 to 5.80%, can be the result of nature of vegetation eaten by camels. Lactose in camel milk can be easily digested by human lactase (Kula and Tegegne, 2016).

2.2.2.4 Minerals

Camel milk has the mineral content ranging from 0.6-0.8% (Farah, 1996). Forage eaten by camels generally has a rich content of salt and as a result, camel milk is a rich source of chloride. Micromineral content varies between breeds. Macrominerals, namely, Ca, Mg, P, Na and K are almost comparable to those of cow milk. Zn, Fe, Cu and Mn concentration is more in camel milk than cow milk. Ca to P ratio for camel milk is 1.5 verses 2.1 and 1.29 for human and cow milk, respectively (Singh *et al.*, 2017).

Table 2.5. Mineral content of camel and cow milk (mg/100 ml)

Na	K	Ca	Mg	P	Reference
Camel milk					
36	60	132	16	58	Gnan and Sheriha, 1986
59	173	115	14	84	Abu-Lehia, 1987
36	62	116	8	71	Hassan et al., 1987
-	-	157	8	104	Farah and Ruegg, 1989
69	156	106	12	63	Mehaia and Al-Kahnal, 1989
Cow milk					
35-60	135-155	100-140	10-15	75-110	Farah, 1993

2.2.2.5 Vitamins

Sawaya et al. (1984) reported that dromedary camel milk had vitamin A content lower than that of cow milk (159 I.U./100 g), while the riboflavin content was lower (1.74 mg/kg) and thiamine content was slightly lower (0.43 mg/kg). Vitamin E, folic acid and pantothenic acid are less in camel milk as compared to cow milk, while pyridoxine and vitamin B₁₂ contents are almost similar

to cow milk. Niacin and vitamin C are substantially higher than that of cow milk (Farah, 1993). Stahl *et al.* (2006) found that vitamin C in camel milk is three to five times more in comparison to cow milk. B-carotene is not detectable in camel milk.

Table 2.6. Vitamin content of camel milk

Vitamin	Content (mg/kg)
Vitamin A	0.15
Thiamine	0.33
Riboflavin	0.42
Pyridoxine	0.52
Vitamin B ₁₂	0.002
Vitamin E	-
Niacin	4.6
Folic acid	0.004
Pantothenic acid	0.88
Vitamin C	24

Source: Sawaya *et al.* (1984)

2.3 FUNCTIONAL PROPERTIES OF CAMEL MILK

Camel milk has many health benefits owing to the presence of protective proteins, which have a role in enhancing immune defense mechanisms. Bioactive compounds also contribute to the therapeutic value. These are present naturally in camel milk or are obtained from protein hydrolysates by either proteolytic enzymes or fermenting milk with lactic acid bacteria (LAB).

Immunoglobulins (I_gG) and secretory immunoglobulins (sI_gA) purified from camel milk are reported to be effective against rotavirus, isolated from bovine and human sources (El-Agamy *et al.*, 1992). ‘Shubat’, a fermented camel milk drink has been found to possess virucidal properties against ortho and paramyxoviruses due to the presence of sialic conjugates and metabolic products of lactic acid bacteria and yeasts (Chuvakova *et al.*, 2000). Camel milk proteins inhibit hepatitis C virus (HCV) entry and replication inside the cell system. Lactoferrin has the ability to completely inhibit HCV entry and replication into human peripheral blood mononuclear cells (PBMC),

hepG2, and replication inside those cell systems (El- Fakharany *et al.*, 2008). Lactoferrin inhibits the growth of *Salmonella typhimurium* by binding iron and making it unavailable for the growth of bacteria (El-Agamy *et al.*, 1992). Empyema, fresh, chronic pulmonary tuberculosis, and multiple drug-resistant patients have been reported to be treated by camel milk (Mal *et al.*, 2006). The primary structure of various food protein sources including milk proteins contains ACE-inhibitory peptides. *Lactobacillus helveticus* 130B4 was reported to release ACE-inhibitory peptides from camel milk with amino acid sequence Ala-Ile-Pro-Pro-Lys-Lys-Asn-Gln-Asp (Quan *et al.*, 2008). Camel milk contains a high amount of insulin or insulin like substances such as half-cystine. Camel milk does not form coagulum in the stomach, allowing camel milk to pass readily and preventing the degradation of insulin or insulin-like peptide, thus promoting anti-diabetic properties. Camel β -casein was found to have higher antioxidant activity after hydrolysis with chymotrypsin. In the study conducted by Moslehisad *et al.* (2013), higher antioxidant activity was observed in camel milk fermented with *Lactobacillus rhamnosus* PTCC 1637 compared to cultured bovine milk. Camel milk contains a lower amount of α s1 casein and β -lactoglobulin, thus acting as a better protein source for children allergic to cow milk (Aburiziza, 2020). Studies have shown that GSH and antioxidant enzymes have a pathophysiological role in autism spectrum disorder (ASD). Camel milk alters the antioxidant enzymes and non- antioxidant molecule levels and also improves the behaviour of autistic children (Gizachew *et al.*, 2014).

2.4 CAMEL MILK PRODUCTS

There is a claim that that camel milk is difficult to be processed into products. But the possibility of various products like fermented camel milk, yoghurt, cheese, butter and camel milk powder has been reported by several workers.

2.4.1 Fermented Camel Milk

In order to extend the shelf life of the camel milk, fermented milk products are being developed. These can be stored at ambient temperatures owing to their antimicrobial properties. ‘Kefir’ is an Eastern European product prepared from camel milk by addition of kefir grains, or modified culture obtained from the grain (Pogacic *et al.*, 2013). Acidic taste of the product is due to the formation of lactic acid and ethyl alcohol during product development (Kavas, 2015). ‘Chal’ or ‘subhat’ is a sparkling beverage in Turkey, white in colour and has a sour flavour (Lakosa and

Shokir, 1964). ‘Dhanaan’ in Ethiopia usually has higher storage stability and can stay for several months when inoculated using batch of milk from previous batch (Seifu, 2007) ‘Gariss’ is a fermented milk product from Sudan, and is made by a semi-continuous fed-batch fermentation process (Dirar, 1993).

Fermented camel milk has a number of health effects as it contains a blend of bio-functional components. During fermentation of β -casein of camel milk, antioxidant peptides are produced (Jrad *et al.*, 2014). Fermented camel milk products can be a good source of potential probiotic strains. *Lactobacillus*, *Bifidobacterium* and *Enterococcus* are the most commonly strains used as probiotic bacteria (Ogier and Serror, 2008). As fermented camel milk contains different lactic acid bacteria, it produces peptides and bacteriocins showing inhibitory activity against many pathogens including *Bacillus*, *Staphylococcus*, *Salmonella* and *Escherichia* reported by various researchers.

2.4.2 Camel Milk Yoghurt

Processing of camel milk into yoghurt has been considered as slightly difficult. Dromedary camel milk does not form firm curd and is fragile consisting of dispersed flakes. It leads to thin consistency and the weaker texture of the product (Attia *et al.*, 2001). Texture is considered as a very important attribute affecting appearance, mouthfeel, and overall consistency. The reason behind the non-fermenting property of camel milk is its antibacterial property due to the presence of protective proteins. However, Hashim *et al.* (2009) have reported that the texture of yoghurt can be improved by adding up of gelatin, alginate and calcium in milk. It is also been suggested that the incorporation of exopolysaccharide producing starter cultures could improve firmness of yoghurt better than additives (Khalifa and Ibrahim, 2015). The thin consistency and weak texture of camel milk yogurt is primarily due to the lack of β -lactoglobulin and lesser amount of κ -casein (Berhe *et al.*, 2017). Furthermore, the ratio of whey protein to casein in camel milk is higher than that of the other dairy source, resulting in thin consistency and weak texture (Hashim *et al.*, 2009).

2.4.3 Camel Milk Cheese

Cheese is derived from milk, and is prepared by coagulation of the milk protein casein. Milk is acidified and rennet enzymes are usually added to coagulate the milk protein. Cheesemaking technology aims to keep the milk for longer periods through lactic acidification and limited dehydration. Although, camel milk processing into cheese is comparatively difficult, owing to its

composition, casein properties and total solids content (Khan *et al.*, 2004). High whey to casein protein ratio, larger micelle size, and lesser amount of κ -casein are responsible for poor cheesemaking properties. This results in not very firm curd and lesser yield of cheese (Bornaz *et al.*, 2009). Although Kappeler *et al.* (2006) suggested that firm curd can be obtained by introducing coding gene for camel chymosin into a mold (*Aspergillus niger*), it did not guarantee good quality of cheese in terms of taste. Technological complications are encountered in camel cheese making, such as continuous serum removal from curd and slow acidification of curd. Camel cheese has weaker crust and dry curd due to rapid removal of moisture. Farah and Bachmann (1987) found that pH decrease from 6.6 to 5 can be achieved in 10 h at 36°C rather than 20°C. *Lactobacillus helveticus*, *L. lactis*, or *Streptococcus thermophilus* can be used as starters to hasten the acidification process (Konuspayeva *et al.*, 2017).

2.4.4 Camel Milk Butter

Butter is made by churning of cream obtained from milk. Size of the fat globules, temperature of cream at the time of churning and fat percentage of cream affects the churnability of cream and body of the butter. The fat content of camel milk is comparable to that of bovine milk, but the melting point of fat is higher (41-43°C) making churning difficult at 10-14°C (Berhe *et al.*, 2013). Camel milk has deficiency of protein agglutinin, thicker fat globular membrane and small sized fat globule, which are responsible for less creaming tendency (Farah, 1996). In addition, it has lesser amount of short chain fatty acids and higher number of long chain fatty acids. The high melting point in camel milk is due to higher number of long chain fatty acids.

However, it has been reported that vigorous shaking of camel milk in a vertical direction at a relatively high churning temperature (22-23°C) extracted butter with 80% fat recovery. It is due to higher force exerted to rupture the fat globules to adhere to each other (Berhe *et al.*, 2013). According to Farah *et al.* (1989), churning temperature between 15-36°C resulted in camel milk butter formation. The churning temperature of 25°C gave highest butter fat recovery of 85%. Camel milk butter is whiter and has viscous consistency while comparing to bovine milk butter.

2.4.5 Camel Milk Powder

The best way to preserve highly perishable milk is to dry it and convert it into powder. Moreover, camel milk is generally available in remote areas and its transportation with minimal nutritional

loss is necessary for global consumption. The two technologies to produce powder from camel milk are spray drying and freeze drying.

Freeze drying or lyophilization is a process in which product is frozen before drying in order to cause minimal degradation reactions and retention of physical, chemical and biological properties (Fonseca *et al.*, 2004). This method is ideal for heat sensitive products. Moreover, shape of the product is also maintained. It was reported in a study of the effect of freeze drying of camel milk on nutritional properties, that most of the components present in milk were stable and that these properties were preserved (Ibrahim and Khalifa, 2015). Several freeze-dried camel milk powders are available in the market (Table 2.7). Freeze drying provides better nutritional and functional properties without causing much alteration in the quality of protein. It is slightly difficult in the case of camel milk due to fat-protein interaction. Physicochemical stability of milk depends upon two critical parameters- water activity (a_w) and glass transition temperature (T_g). Although freeze drying provides better quality of powder, it is an expensive process.

Table 2.7 Commercially available freeze-dried camel milk powders

Brand	Quantity/ ₹
Aadvik	500 g/ 3000
Hye Foods	300 g/ 399
Amul	250 g/ 350
Nutra Vita	1 kg/ 7000
Pankti	100 g/ 799
Thar Food	50 g/ 310
As Fresh	100 g/ 800
Urban Platter	100 g/ 500
Porta bites	96 g/ 574

Generally, spray drying is considered as a better method of camel milk powder production, due to the better reconstititional properties of the product. Spray drying of camel milk necessitates optimization of the input parameters such as temperature, pressure and flow in order to maintain the nutritional properties of the product as well as its functional characteristics (solubility,

hygroscopy, and fluidity). But the high heat treatment during spray drying results in denaturation of proteins. It is very essential to maintain powder in its original condition. Surface composition is an important attribute, which facilitates solubility of powder (Vega *et al.*, 2006). The surface of the spray dried emulsion generally consists of fat and some proteins. On heating protein denatures, thus leaving fat as the major component on the surface making it difficult to restore the liquid milk. Encapsulation using sodium caseinate can be considered for a construction of a better emulsion (Konuspayeva and Faye, 2021). Spray dried camel milk powder has been found to cause reduction in water activity and increase in glass transition temperature (T_g) on increasing outlet drying temperature. Bharati (2020) optimized the process for spray drying camel milk as per protocol given in Fig. 2.1.

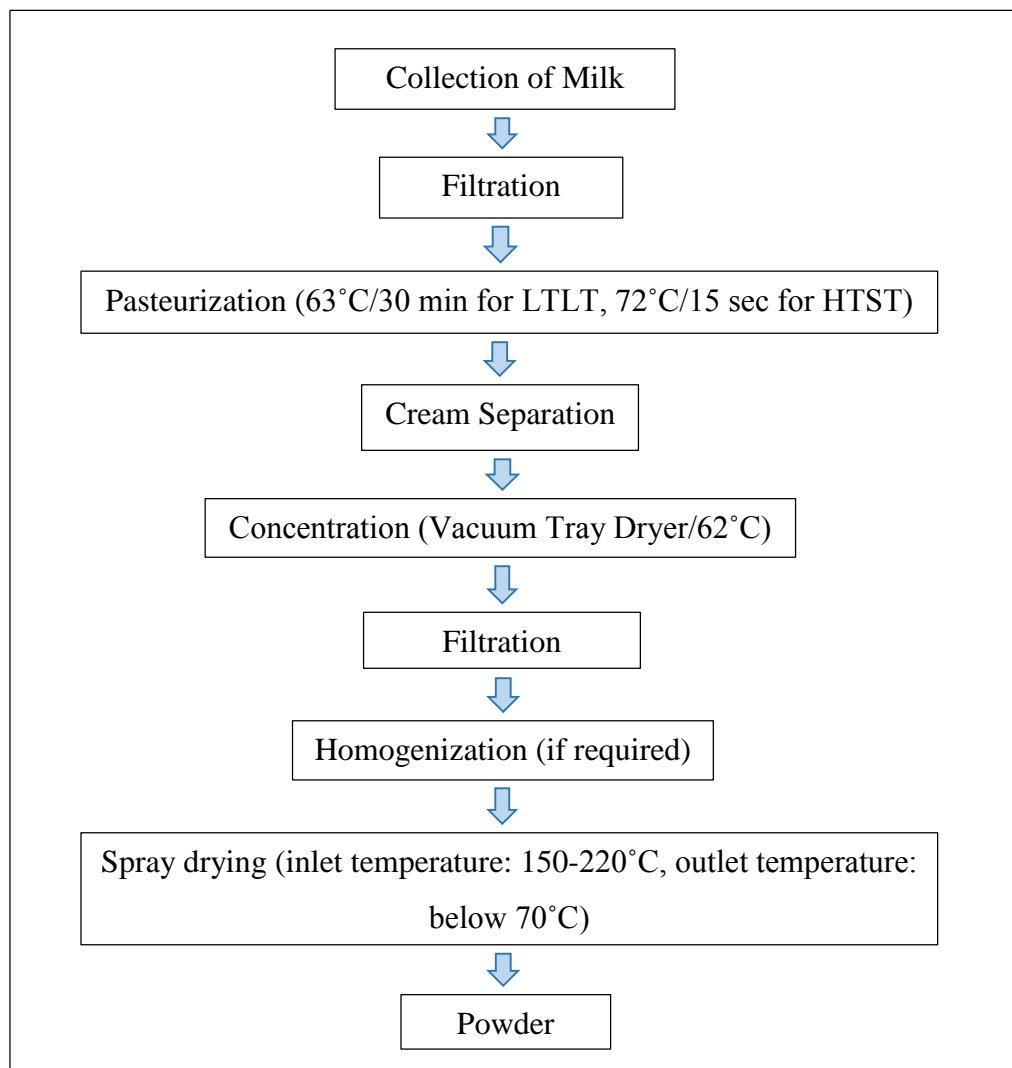


Figure 2.1 Flow chart for the preparation of camel milk powder (Bharati, 2020)

The variables taken for the study were inlet temperature of spray drying, feed rate and concentration of camel milk before drying. It was observed that with increase in inlet air temperature (200°C), feed rate of about 25 mL/min and total solids 25%, there was a decrease in moisture content, which may be helpful in increasing its shelf life during storage. On the other hand, on increasing inlet temperature whey protein nitrogen index (WPNI), hydroxymethyl furfural and free fat content of the powder was raised, resulting in change of brightness. Lowering the air inlet temperature with constant feed and concentration resulted in better reconstititional properties like emulsion capacity, emulsion stability, foam capacity, foam stability, and water and oil binding capacity. However, the hygroscopicity of the product was thought to have a detrimental effect on the overall acceptability of powder on storage. It was finally concluded that low inlet air temperature of 180°C with 25 mL/min feed rate and 25% total solid content could be a better combination of processing variables for powder manufacturing as it resulted in lesser nutrient loss and better color appearance.

2.5 GENERAL PROPERTIES OF MILK POWDER

2.5.1 Particle Size

Appearance, reconstititional properties and flowability are related to particle size. It is influenced by the original milk characteristics, processing conditions and the equipment used in the process of drying (Anon, 2000). Agglomerated milk powder has larger and more irregular shaped particles (Caric, 1994). Increase in the percentage of fine particles (<90 µm) decreases the dispersibility of powder (Singh and Newstead, 1992).

2.5.2 Bulk Density

Bulk density is mass of milk powder, which occupies a fixed volume and is expressed as g/cm³. Increasing the total solids of concentrate increases bulk density, as occluded air decreases and so the volume decreases. Bulk density is categorized in 4 ways (Barbosa-Canovas and Juliano, 2005):

1. Compact density: It is determined when powder's bulk mass is compressed by mechanical pressure, vibration and impact.
2. Tap density: When volume of powder is tapped or vibrated under specific conditions, tap density is determined.
3. Loose bulk density: It is measured by freely pouring the powder into a container.

4. Aerated bulk density: It is determined when the powder is aerated, generally in pneumatic conveying applications or under fluidized conditions. Particles are separated from each other by a film of air.

2.5.3 True Particle Density

It is the ratio of mass of particle to volume of particle, without considering pores in the material. It indicates how close the material is to crystalline state.

2.5.4 Flowability

It is the ease with which the particles flow with respect to each other. Flowability is evaluated in terms of Carr's index (CI) and Hausner ratio (HR) (Reddy *et al.*, 2014). Powder with large agglomerates and few fines have good flowing properties. Proper flow is important for packaging, transportation and measuring. Powders with high fat content possess lower flowability reported by Fitzpatrick *et al.* (2004). Better flowability is attained when low melting point fat is crystallized to medium and high melting fat fractions. Cohesion and compressibility directly influences the powder properties. Flowability is inversely proportional to cohesion and compressibility (Thomas *et al.*, 2004). The angle of repose of 32.5° and compressibility 0.029 indicate good flowability characteristics (Sang-Cheon *et al.*, 1993).

2.5.5 Wettability

Ability of a powder to absorb water on the surface, to be wetted, and to penetrate the surface of still water is wettability. Lower the contact angle between solid and liquid, greater the wetting (Sharma *et al.*, 2012). Large particles with high porosity favours fast wetting. Agglomeration helps to increase size of milk protein and high porosity granules due to the formation of void structures (Turchiuli and Castillo-Castaneda, 2009). Wettability is influenced mainly by hydrophobicity of milk protein powders in comparison to structural properties (Ji *et al.*, 2016). 'Instant' milk powders are the ones which wet easily and quickly. Hygroscopic components like lactose on surface yields good wetting properties due to small contact angle (Faldt and Bergenstahl, 1996; Kim *et al.*, 2002). Swelling of particles results in slower wetting.

2.5.6 Sinkability

It refers to the ability of powder to overcome the surface tension and sink in the water, expressed as milligrams of powder that sink per minute per cm² surface area (Schober and Fitzpatrick, 2005). If particle density is high and occluded air is low, then sinkability will be higher. The process of ‘instantization’ increases sinkability by causing increase in weight through agglomeration.

2.5.7 Dispersibility

Dispersibility is the ability to separate lumps and agglomerates into individual particles when dispersed in water. It leads to decrease in the particle size. It is expressed as percentage of solids dissolved. Whole milk powder has less dispersibility ($\geq 85\%$) than skim milk powder ($\geq 90\%$) (Tamime, 2009). Dispersible powders are agglomerated and have good wettability. Agglomeration of micellar casein powders extends dispersion time as it only modifies structure. Addition of mineral salts can destruct the micellar structure and increase the dispersion rate (Ji *et al.*, 2016).

2.5.8 Solubility

Solubility index is a measure of undissolved residue or sediment that remains after dissolving milk powder in water. Solubility depends on chemical composition and physical state of powder. Insolubility is due to unfolding of β -lactoglobulin and then aggregation with casein. The main factor that controls insolubility index is the particle temperature during drying, when moisture content is between 10% and 30% (Sharma *et al.*, 2012). Spray dried skim milk powder, whole milk powder and partially skimmed milk powder has more solubility ($> 99\%$) than tray dried cheese powder ($\sim 91\%$) followed by roller dried milk ($\sim 85\%$) (Tamime, 2009).

2.5.9 Hygroscopicity

Water absorption property is of great importance in terms of selecting packaging material and storage conditions. This depends upon lactose and milk protein. Some properties such as viscosity, gelation, emulsifying property, swelling and foaming capacity are affected by interaction of protein and water. They are expressed as sorption-desorption isotherms. At water activity less than 0.3, monolayer is formed due to strong protein-water interaction while at greater than 0.3, multilayer is formed. Amorphous lactose is hygroscopic and at higher relative humidity it absorbs water sharply (Thomas *et al.*, 2004).

2.5.10 Foaming Properties

Foaming power refers to the ability to stabilize air-water interface to create a foam. It is the increase in volume after whipping. It is expressed as foam overrun. Foaming stability is the time before powder collapses by external causes. Lowering the pH improves foaming overrun, whereas foam stability improves at high pH (Augustin and Clarke, 2008). Both casein and whey proteins contribute to foaming properties. Casein adsorbs on the interface preferentially to whey proteins. Added salts like citrate and phosphate increases foam overrun and foam stability.

2.6 PROPERTIES OF CAMEL MILK POWDER

2.6.1 Composition

Gross composition of camel milk powder showed that the moisture content is $4.61 \pm 0.74\%$ which corresponds to $0.34 \pm 0.01 a_w$, $24.59 \% \pm 0.01$ (w/w) protein, 23.17 ± 0.29 (w/w) fat, and 43.57 ± 0.91 (w/w) lactose. The inlet and outlet temperature used for drying air used were 160° and 70°C respectively, with compressed air set at 40kPa (Ho *et al.*, 2019). Deshwal *et al.* (2020) reported that at an inlet and outlet temperature of $170 \pm 5^\circ\text{C}$ and $70 \pm 5^\circ\text{C}$, respectively, and feed rate of 50 ml/min, the resultant powder had the composition listed in Table 2.8.

Table 2.8 Chemical composition of spray dried camel milk powder

Parameters	Composition
Total solids (g/100g)	97.57 ± 0.15
Moisture (g/100g)	2.43 ± 0.15
Fat (g/100g)	28.23 ± 0.40
Protein (g/100g)	27.44 ± 0.94
Lactose (g/100g)	32.62 ± 0.68
Ash (g/100g)	9.27 ± 0.89
Water activity	0.193 ± 0.01

Source: Deshwal *et al.* (2020)

Zouari *et al.* (2020b) compared the chemical composition of cow and camel milk powder (Table 2.9). It was concluded that protein as well as fat content in camel and cow milk powders were similar for whole as well as skimmed milk powders. There was no relation between water

activity and fat content of the powders as fat has no interaction with water. However, lactose contents increased significantly by the removal of fat in both the cases.

Table 2.9 Physicochemical characteristics of cow and camel milk powders

Parameters	WDMP	PSCMP	SDMP	SCMP
a_w	0.250 ± 0.01	0.249 ± 0.01	0.251 ± 0.01	0.249 ± 0.01
Total solids	96.9 ± 0.4	96.5 ± 0.4	96.8 ± 0.5	96.3 ± 0.1
Lactose	40.7 ± 0.1	40.4 ± 0.2	52.7 ± 0.2	54.0 ± 0.2
Proteins	27.3 ± 0.5	27.8 ± 0.1	33.3 ± 0.2	33.5 ± 0.5
Caseins	20.3 ± 0.5	22.1 ± 0.1	25.8 ± 0.2	27.3 ± 0.4
Whey	7.0 ± 0.3	5.8 ± 0.1	7.4 ± 0.1	6.2 ± 0.1
Total fats	20.5 ± 0.2	21.0 ± 0.5	1.0 ± 0.1	1.0 ± 0.1
Ash	8.4 ± 0.1	7.1 ± 0.1	8.8 ± 0.1	7.8 ± 0.1

WDMP: whole camel milk powder; PSCMP: partially skim cow milk powder; SDMP: skim camel milk powder; SCMP: skim cow milk powder; composition expressed in $g\ 100g^{-1}$.

Source: Zouari *et al.* (2020b)

2.6.2 Solubility

Camel milk powder dissolved almost completely in water with a solubility of $98.62 \pm 1.47\%$. Solubility is affected by relative humidity (RH). The greater the RH, higher is the solubility loss. It was reported that the reason might be cross-linking of the proteins due to either hydrophobic association of casein micelles or Maillard reaction. Glyoxal or methylglyoxal on reacting with lysine and arginine result in cross linking of proteins. Also, crystallisation of lactose in milk powders leads to the spreading of lipid on the surfaces, together with free fat present, providing a barrier to hydrophobic interactions between the milk powder and water (Ho *et al.*, 2019). Deshwal *et al.* (2020) reported $65.47 \pm 0.46\%$ solubility in camel milk. Large droplets of milk require intense heating to dry completely, leading to increased amount of denaturation of whey protein, which may decrease the powder solubility. Zouari *et al.* (2020a) had reported higher percent solubility for camel milk powder (96.4%), the insolubility index ranging from 1.21-1.37 ml. Spray drying results in lower insolubility index (Sulieman *et al.*, 2014).

2.6.3 Colour

L* value is an indication of lightness (L= 100) and darkness (L= 0), a* value is the indication of redness (+ value) and greenness (- value), and b* value is the indication of yellowness (+ value) and blueness (- value). Deshwal *et al.* (2020) reported L*a*b values of 82.48±0.51, 3.97±0.12, and 11.92±0.50, respectively, in camel milk powder. . Colour of camel milk powder is usually white, but changes with storage, due to non-enzymatic browning reactions. The a* values of camel milk powder samples were higher than goat milk powder (Reddy *et al.*, 2014) and cow milk powder (Sulieman *et al.*, 2014) due to presence of lactoferrin (redness) and riboflavin (greenness) in camel milk.

2.6.4 Flowability

Camel milk powder has good flowability. Carr's index and Hausner ratio determine flowability. The specifications for the indexes are mentioned in Table 2.10. Hausner ratio generally remains unaffected by the parameters like type of drying, concentration of feed, feed flow rate and drying temperature of the spray dryer, but changes with the direction of feed (Sulieman *et al.*, 2014). For good flowability, Carr's index or compressibility ratio must be lower than 15% and Hausner's ratio must be lower than 1.18 (Lebrun *et al.*, 2012). Carr's index of camel powder was found to be 18.63±0.73% and Hausner ratio, 1.22±0.12 (Deshwal *et al.*, 2020).

Table 2.10 Specifications for Carr's index and Hausner's ratio

Flowability	Carr's index	Hausner's ratio
Excellent	0-10	1.00-1.11
Good	11-15	1.12-1.18
Fair	16-20	1.19-1.25
Passable	21-25	1.26-1.34
Poor	26-31	1.35-1.45
Very poor	32-37	1.46-1.59
Very, very poor	>38	>1.60

(Source: Lebrun *et al.*, 2012)

2.6.5 Bulk Density

Increase in dry matter, non-uniform particles and skimming leads to increase in bulk density. Bulk density is affected by the method of drying used. For all preparations of spray dried camel milk powder, bulk density and tapped bulk density was found to be in the range of 0.34-0.41g/ml and 0.45-0.53 g/ml, respectively (Suliman *et al.*, 2014). Due to occlusion of air in particles during spray drying, bulk density of camel milk powder is lower than expected (Pisecky, 1987). Higher denaturation of whey proteins and raising total solids content results in lower amount of occluded air leading to higher bulk density, while increase in feed rate and drying temperature decreases the bulk density (Fitzpatrick and O'Callaghan, 1996). Camel milk powder density shows no significant changes with change in RH (11, 22 and 32%) as reported by Ho *et al.* (2019). Untapped density is influenced by type of drying, while tapped density is affected by type of milk and type of drying. Spray drying produces less porous particles due to initial expansion of air followed by collapse of particles. Deshwal *et al.* (2020) reported that loose bulk density and packed bulk density of camel milk powder were 0.424 ± 0.02 g/ml and 0.522 ± 0.03 g/ml, respectively.

2.6.6 True Density

True density of the powder gets affected by the moisture content and the structure of powder. Crystalline powder has higher true density as compared to amorphous one as atoms are aligned at shortest distance possible causing reduction in volume (Yang *et al.*, 2012). True volume of powders increases with increase in moisture content, causing increase in true density (Oginni, 2014). Although, true density of microcrystalline cellulose remained constant in the range of moisture content 3.30-5.10%, but changes beyond this (Sun, 2008).

2.6.7 Particle Size Distribution

Freshly prepared spray-dried camel milk powder was found to have average particle size of 3.34 ± 0.08 μm , which increased during storage. Increase in the relative humidity during storage leads to increase in particle size (Ho *et al.*, 2019). Caking of the powder is observed during storage. This might be either due to melting of lipid present in the powder or crystallization of lactose (Bhandari, 2007). It causes deterioration in quality and loss of solubility. In a comparative study of whole freeze dried (FDW), spray dried skim camel milk powder (SDS) and spray dried whole camel milk powder (SDW), Deshwal *et al.* (2020) found that FDW had higher particle size

distribution followed by SDW and SDS. Ogolla *et al.* (2019) suggested that particle size of SDW decreased by increasing inlet air temperature and decreasing flow rate of milk. Ho *et al.* (2019) described that the particle size of spray dried camel milk powder which was 3.34 μm initially, increased as storage proceeded.

2.6.8 Structure of Powder Particles

Whole milk powder had a smooth surface covered by fat layers, while skimmed milk powder showed rough, 'brain' like structure (Zouari *et al.*, 2020b). Fat on the surface has a tendency to fill pores, thus inhibiting the movement of water to the surface. Thus, skimmed milk powder has more wrinkled and collapsed structure. Camel milk fat globules were encapsulated by the proteins near the powder surface and milk fat behavior during particle formation was due to their lower size distribution and higher crystallization temperature (Zouari *et al.*, 2020b). According to Ho *et al.* (2019), particles of spray dried camel milk powder were spherical in shape having wrinkled and folded surface. Some dents and large vacuoles were formed on the surface. During the storage at different relative humidity, shape of the powder remained unchanged but agglomeration increased, especially for the one kept at 32% RH. The reason for agglomeration could be the presence of free fat on the surface (Kim *et al.*, 2002). During storage of milk powders, change in morphology is marked by the lactose crystallization (Thomas *et al.*, 2004).

2.6.9 Fat Oxidation

Fat oxidation is generally initiated by the formation of free radicals, peroxides and hydroperoxides due to reaction of lipids with atmospheric oxygen. Consequently, free radicals react with unsaturated lipids to produce secondary oxidation products such as alcohols, esters, ketones, aldehydes, aromatic hydrocarbons leading to changes in colour and odour of milk powders (Lee and Morr, 1994). During storage, camel milk powders kept at relative humidity of 11% showed higher fat oxidation as compared to the powders kept at relative humidity of 22 and 32% (Ho *et al.*, 2019). The rate of fat oxidation varies inversely with water activity. Monolayer of water covers the fat surface at higher a_w , preventing the direct contact with air (Roos, 2002). In contrast to this, Stapelfeldt *et al.* (1997) reported that whole cow milk powder stored at 45°C retained its highest quality at a_w of 0.11-0.23 as compared to 0.33 a_w , which exhibited increase in fat oxidation. This had been explained that at 0.33 a_w , fat is more accessible to oxygen as well as catalysts. However,

correlation of a_w and fat oxidation is difficult as during storage of milk powders, products of Maillard reaction acts as antioxidants (Lee and Morr, 1994).

2.6.10 Moisture Sorption Isotherm

Equilibrium moisture content is higher at lower temperature due to higher water binding capacity of proteins and carbohydrates. It increases with increasing water activity. Monolayer moisture content decreased from 1.07 g/100 g at 25°C to 1.041 g/100g at 35°C in accordance with GAB model (Deshwal *et al.*, 2020). Dairy powders are very hygroscopic, so they absorb water from ambient surrounding. Monolayer moisture content for skim camel milk powder using GAB model was 2.0 ± 0.2 g/100g and 'C' value which represents surface hygroscopicity, 20.0 ± 1.9 (Zouari *et al.*, 2020a). Monolayer moisture content for both skimmed camel milk powder and skimmed bovine milk powder was found to be significantly similar. However, the constant 'C' was higher for skimmed bovine milk powder. 'C' constant describes water energy binding by the monolayer or surface hygroscopicity. Zouari *et al.* (2020b) revealed that skimmed camel milk powder contains double the amount of lactose in comparison to skimmed cow milk powder, leading to higher mobility and low stability of lactose. This explains the higher lactose crystallization and water binding energy for skim camel milk powder.

2.6.11 Storage Studies

Ho *et al.* (2019) stored spray dried camel milk powder at three different relative humidities (11-32%) at 37°C for 18 weeks and studied various parameters. Moisture content of the powder either increased or decreased depending on the relative humidity of the surrounding environment. Powder loses or gains moisture till it attains equilibrium moisture content. Solubility of the powder decreases on storage. Change in moisture content, solubility and yellowness/blueness were more profound for higher RH. There was slight development of crystallinity, fat oxidation and non-enzymatic browning. Secondary structure of proteins unfolded from α -helices to β -sheets.

2.7 EFFECT OF PROCESS PARAMETERS ON QUALITY OF POWDER

Conditions applied during processing impart different characteristics of final particles, such as different morphologies, sizes or residual moisture contents etc., to powders. Several studies have

been carried out on effect of process parameters on spray dried camel milk powder. Optimization of drying process is important to obtain products with high functional properties.

2.7.1 Atomization Pressure

Atomization is the process of converting milk into fine droplets, which takes place under pressure. This pressure has an impact on size of droplet. With increase in pressure, droplet size decreases. Finer droplets will result in loss of volatile components like vitamin C. If atomization pressure increases, spray flows straight downwards as a result increases cyclone recovery, where towards the wall when pressure decreased. High atomization pressure increases the fatty acid content due to breakdown of feed into smaller droplets, which facilitates oxidation reactions more on unsaturated fatty acids (Habtegebriel *et al.*, 2018b).

2.7.2 Feed Flow Rate

Recovery of powder decreases with increase in feed flow rate. Lower feed rate increase residence time and increase the chances of drying. If feed flow rate is high, feed will pass without proper drying. Decreasing the feed flow rate increases the cyclone recovery (Habtegebriel *et al.*, 2018b). It is also influenced by interaction between atomization pressure and inlet temperature. Moisture content of powder increases with decrease in feed rate. Feed rate influences bulk density and reconstititional properties (Ogolla *et al.*, 2019).

2.7.3 Inlet Temperature

Increase in inlet temperature increases total solids in cyclone recovery due to increase in thermal efficiency. It also results in rise in outlet temperature for having a direct relation with it (Habtegebriel *et al.*, 2018a). But increase inlet temperature also causes an increase in wet bulb temperature of surrounding air. Low inlet temperature therefore lowers surrounding air wet bulb temperature and prevents thermal degradation of the final product. Moisture content was affected by inlet dry air temperature and as a result, colour properties changed (Ogolla *et al.*, 2019). Although, increase in inlet drying air temperature decreases the bulk density (Bansal *et al.*, 2014), lower spray drying temperatures are important to minimize the solubility loss of camel milk proteins. Fat, which is present on the surface causes aggregation of neighbouring particles (Habtegebriel *et al.*, 2018a).

2.7.4 Outlet Temperature

Low outlet temperature lead to low denaturation and solubility loss. High outlet temperatures can lead to loss of vitamin C and cause denaturation of α -helix of whey protein to β -sheet. Habtegebriel *et al.* (2018b) reported little degradation at 60-80°C, higher at more than 90°C and complete denaturation at 120°C. On increasing the outlet drying temperature, there was a significant increase in the glass transition temperature and decrease in the water activity as well as powder density (Zouari *et al.*, 2017). Outlet temperature directly related with cyclone recovery and yield of powder.

2.7.5 Direction of Feed and Air

The direction of feed had an effect on physicochemical properties of camel milk powder. Hausner's ratio obtained by co-current feeding is lower than counter-current, hence it is more flowable. Co-current feeding produced more lightness and greenish color, while counter-current feeding resulted in more degree of redness. Yellowness was more in counter-current feeding. Further, protein content was found to be more in co-current feeding (Sulieman *et al.*, 2014).

2.7.6 Mode of Drying

Deshwal *et al.* (2020) studied the effect of freeze drying and spray drying on physiochemical properties, functional properties, moisture sorption isotherms and morphological characteristics of camel milk powder prepared from skim and whole milk (Table 2.11). It was found that freeze dried powder had more retention of calcium and iron. Freeze dried whole milk powder had the highest water binding capacity while least was in spray dried whole milk powder. Freeze dried sample had porous sheet like structure while spray dried sample had agglomerates of individual spherical particles. In case of moisture sorption isotherms, equilibrium moisture content of samples was higher at lower temperature due to water binding capacity of proteins and carbohydrates. Monolayer moisture content was highest for spray dried skim milk powder due to its high protein content. Unfolding of protein structure exposed more sorption sites. The value of M_0 by GAB model was more than what was reported by Zouari *et al.* (2020a).

Table 2.11 Physicochemical, reconstititional and functional properties of freeze dried whole camel milk powder (FDW), spray dried skimmed camel milk powder (SDS) and spray dried whole camel milk powder (SDW)

Parameters	FDW	SDS	SDW
Total solids (g/100g)	97.19 ± 0.16	94.89 ± 0.06	97.57 ± 0.15
Moisture (g/100g)	2.81 ± 0.16	5.10 ± 0.07	2.43 ± 0.15
Fat (g/100g)	27.83 ± 0.51	1.15 ± 0.04	28.23 ± 0.40
Protein (g/100g)	28.29 ± 0.29	32.23 ± 0.63	27.44 ± 0.94
Lactose (g/100g)	31.39 ± 0.39	50.01 ± 0.78	32.62 ± 0.68
Ash (g/100g)	9.66 ± 0.79	11.49 ± 0.86	9.27 ± 0.89
Acidity (g/100 g lactic acid)	0.193 ± 0.01	0.202 ± 0.006	0.211 ± 0.008
Water activity	0.214 ± 0.02	0.174 ± 0.004	0.193 ± 0.01
Calcium (g/kg)	15.33 ± 0.61	13.71 ± 0.234	13.92 ± 0.79
Iron (g/kg)	0.012 ± 0.001	0.011 ± 0.002	0.011 ± 0.004
Hunter color values L*	86.73 ± 3.01	94.83 ± 0.74	82.48 ± 0.51
a*	-1.20 ± 0.18	1.84 ± 0.47	3.97 ± 0.12
b*	10.23 ± 0.33	8.30 ± 0.59	11.92 ± 0.50
Loose bulk density (g/ml)	0.348 ± 0.01	0.370 ± 0.06	0.424 ± 0.02
Packed bulk density (g/ml)	0.516 ± 0.024	0.549 ± 0.04	0.522 ± 0.03
Particle density (g/ml)	0.862 ± 0.05	0.931 ± 0.08	0.824 ± 0.01
Carr index (%)	32.44 ± 2.91	45.05 ± 5.47	18.63 ± 0.73
Hausner ratio	1.34 ± 0.06	1.48 ± 0.04	1.22 ± 0.12
Wettability (s)	67.15 ± 0.38	50.68 ± 0.82	53.96 ± 0.97
Dispersibility (%)	8.47 ± 0.15	4.51 ± 0.06	6.57 ± 0.08
Particle size distribution (µm) d ₅₀	24.74 ± 0.29	13.81 ± 0.15	19.25 ± 0.42
d ₉₀	51.95 ± 0.53	26.94 ± 0.19	42.75 ± 0.77
Solubility (%)	88.77 ± 0.64	72.96 ± 0.20	65.47 ± 0.46
Foaming capacity (%)	25.41 ± 0.43	49.85 ± 0.49	40.88 ± 0.49
Foaming stability (%)	77.71 ± 0.86	90.91 ± 0.53	84.99 ± 0.59

Source: Deshwal *et al.* (2020)

2.8 EPILOGUE

The preceding review presented the research reports the health benefits of camel milk and how it can be used against various ailments due to the presence of anti-viral, anti-carcinogenic, anti-hypertensive, anti-diabetic activities and high immunoglobulin content conferring antimicrobial properties. However, global availability of camel milk is still a major problem and drying was suggested as the best technique to preserve the milk. Freeze drying produced a remarkable product, though it comes with higher production cost. Spray drying has become the interest of several researchers, who have optimized the processing conditions. Although camel milk powder with optimum properties was produced, the change of those properties during storage have not been elucidated completely, particularly, the effect of variations in the storage temperature.

Considering all these facts, the present study titled **Storage Studies of Spray Dried Camel Milk Powder** is being undertaken with the following objective:

To study the effect of storage on physicochemical, reconstititional and functional properties of camel milk powder.

3. MATERIALS AND METHODS

This chapter contains the information pertaining to materials including equipment used during the course of research, methods employed and analytical techniques involved for reconstituted, functional and microbiological analysis of camel milk powder during storage.

3.1 MATERIALS

Camel milk powder standardized in an earlier project (Bharati, 2020) was used for the study. Single layered Aluminium pouches were used for packaging. Media for microbiological analysis (i.e., Plate Count Agar (PCA), Violet Red Bile Agar (VRBA) and Potato Dextrose Agar (PDA) for different microbiological analysis were procured from Himedia, Laboratories Ltd. (Mumbai). All chemicals used for analyses were of analytical grade and purchased from standard manufacturers.

3.2 METHODS

Camel milk powder was packed in aluminium pouches, stored at 25°C, 37°C, and 45°C and evaluated for various physiochemical, functional and reconstituted properties at intervals of 20 days during the storage period of 150 days.

3.2.1 Proximate Composition

3.2.1.1 Moisture and total solids

The moisture content was determined as per IS 16072:2012. Weight of empty, clean and dried aluminium dish was recorded and one gram of the powder sample was transferred in it. The dish was kept in the oven at 102±2°C for 2 h, then transferred to desiccator and allowed to cool and weighed quickly. The dish was again placed in the oven at 102±2°C for further 1 h, allowed to cool in the desiccator and weighed accurately. The process of heating and cooling was repeated until successive weights did not differ by more than 0.5 mg.

$$\text{Moisture, percent by mass} = (M_1 - M_2 / M_1 - M) \times 100$$

where

M_1 = initial mass of the dish and lid with the material taken for analysis in g;

M_2 = final mass of the dish and lid with the material after drying in g;

M = mass of the empty dish in g.

Total solids were then calculated by the following formula:

Total solids = Total mass of the product – moisture percent by mass

3.2.1.2 Protein

Protein content of the powder was determined by the Macro Kjeldahl method (IDF 20 B: 1993) using Pelican Kelplus – KES 06L VADLS digestion assembly (Pelican Equipment, Chennai, India), followed by distillation by Kjeldahl Automatic Nitrogen Distillation Unit and titration (Model: KELPLUS SUPRA-LXVA).

Digestion: Three grams of the Kjeldahl catalyst (potassium sulphate and copper sulphate in the ratio 9:1) was added in each of clean and dry Kjeldahl flasks (500 ml) flask, followed by 2 g of the powdered sample. Any residues left on the neck of the digestion flask were washed by the addition of 25 ml of sulphuric acid (density = 1.84 g/ml). For blank reading, only digestion mixture and sulphuric acid were added to the flask. These flasks were kept in the digestion assembly and digestion was continued at 420°C temperature until clear solution was obtained.

Distillation: After complete digestion of the sample, it was cooled to remove all the fumes. The digested sample was transferred to the 100 ml volumetric flasks. Any residue left was removed with the help of distilled water. Volume was made to 100 ml using distilled water to dissolve any crystals. Distilled water was added gradually from the corners of the flask to avoid brisiking. Solutions of sodium hydroxide (40%) and boric acid (4% were prepared. Further, 3 ml of the mixed indicator containing methyl red and bromocresol green in the ratio 3:1 was added in 1 L of boric acid. Both the acid and the alkali prepared were filled in the flasks in the distillation unit. First the inlet pipes were immersed in warm distilled water and washing of the unit was done. Then, after mixing the diluted samples thoroughly, 10 ml of the sample was taken in distillation flask and inlet pipes were immersed in sodium hydroxide and boric acid. Distillation was started and distillate was collected in a conical flask. First, distillation of the blank was done followed by the samples.

Titration: The distillate was removed from the distillation assembly and was titrated against 0.01 N HCl. The appearance of the slight pink colour indicated the end point. The titre volume was noted. The protein content was calculated as follows:

$$\text{Protein (\%)} = \frac{(A-B) \times N \times 1,4007 \times 6.25}{W}$$

where

A = volume (ml) of 0.2 N HCl used sample titration

B = volume (ml) of 0.2 N HCl used in blank titration

N = Normality of HCl

W = weight (g) of sample

14.007 = atomic weight of nitrogen

6.25 = the protein-nitrogen conversion factor for fish and its by-products

3.2.1.3 Fat

Fat content in powder was determined by Rose-Gottlieb method as given in IS: 1479 (Part II) - (1961) for milk. About 10 g of the powder was weighed and transferred to the extraction tube. Ammonia (1.25 ml, specific gravity 0.91, or an equivalent volume of more concentrated solution of ammonia) was added and shaken thoroughly. Ten ml of ethyl alcohol was further added and the contents were mixed thoroughly. Then, 25 ml of diethyl ether (peroxide free) was added and neck of the tube was closed by the glass stopper and shaken vigorously for about a minute. Further, 25 ml of petroleum ether (boiling range 40-60 °C) was added and shaken vigorously for 30 sec. The tube was kept undisturbed till upper ethereal layer has separated completely. The clear ethereal layer was transferred to clean, dried and weighed aluminium dish. The liquid remained in the extraction tube was extracted twice using 15 ml each of diethyl ether and petroleum ether, and ethereal layer was added to the same aluminium dish. Petroleum ether was then evaporated using water bath at about 50-60 °C. The dish was then dried in the oven at 102±2 °C for 2 h, cooled in a desiccator and then weighed. The difference in the weight of aluminium dish before and after evaporation of solvent gives the fat extracted from powder.

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

3.2.1.4 Ash

Ash was determined by the method described by AOAC (2000). Five g of the sample was weighed in a silica crucible and heated in a Bunsen flame till charred completely. The crucible was then placed in a muffle furnace at 550°C for 5-6 h and then cooled in a desiccator. The weight of the ash was recorded.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.2.1.5 Lactose

Lactose was determined by the difference method by subtracting protein, fat and ash from total solids.

$$\text{Lactose (\%)} = \text{Total solids \%} - (\text{Protein \%} + \text{Fat \%} + \text{Ash \%})$$

3.2.2 Moisture Sorption Isotherm

The moisture sorption isotherms of camel milk powder were generated as explained by Kumar *et al.* (2015). Table 3.1 gives the proportion of different salts to water for the preparation of salt slurries used. These salt slurries were then equilibrated at 15°C, 30°C and 45°C.

Table 3.1. Preparation of recommended saturated salt solutions

Salt	RH (%)	Salt (g)	Water (ml)
Lithium chloride	11.25	150	85
Potassium acetate	22.60	200	65
Magnesium chloride	32.73	200	25
Potassium carbonate	43.80	200	90
Magnesium nitrate	52.86	200	30
Sodium nitrate	65.8	100	100
Sodium chloride	75.32	200	60
Potassium chloride	84.32	200	80
Potassium nitrate	93.60	200	80

Camel milk powder sample was mixed with 0.5% potassium sorbate (w/w) in order to prevent mold growth. Moisture content of the sample was measured before keeping in the sample jars. One g sample was weighed in 10 ml beaker, which was then transferred to 50 ml beaker containing marbles. Finally, it was kept in prepared equilibrated salt solutions of different water activities, in sorption jars in triplicate. These were then stored at 15°C, 30°C and 45°C. Weight of the sample

was measured at intervals of 2 days till the sample attained equilibrium (or the difference between consecutive weights was less than 2 mg). The equilibrium moisture content (EMC) was calculated as follows:

$$\text{Change in moisture content (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

where, W_1 = Initial sample weight, W_2 = Final sample weight

EMC on wet basis (%) = Change in moisture content + Initial moisture content

$$\text{EMC on dry basis (\%)} = \frac{EMC}{100 - EMC} \times 100$$

3.2.2.1 Generation of Sorption Isotherm Models

3.2.2.1.1 Two Parameter Model

A graph between EMC and a_w was plotted and straight line equation was calculated. Data was fitted in the following equation.

$$\text{Brunauer, Emmet and Teller (BET): } \frac{M}{M_0} = \frac{C a_w}{(1 - a_w)(1 - a_w + C a_w)}$$

$$\text{BET Linear equation: } \frac{a}{(1 - a_w)M} = \frac{1}{M_0 C} + \frac{C - 1}{M_0 C} a_w$$

where,

M = equilibrium moisture content, M_0 = monolayer moisture content, C = constant, a_w = water activity

Straight line equation: $y = mx + c$

Comparing both equations,

$$y = \frac{a}{(1 - a_w)M}, m = \frac{C - 1}{M_0 C}, c = \frac{1}{M_0 C}$$

3.2.2.1.1 Three Parameter Model

A graph between a_w and a_w/M was plotted and quadratic equation was calculated. Data was fitted in the following equation.

$$\text{Guggenheim, Anderson and deBohr (GAB): } M_0 C K a_w / (1 - K a_w)(1 - K a_w + C K a_w)$$

where,

M = equilibrium moisture content, M_o = monolayer moisture content, C, K, G = constant, a_w = water activity

GAB Linear equation: $aw/M = C1 + C2aw + C3(aw)^2$

Where, $C1 = \frac{1}{MoCK}$, $C2 = \frac{1-2C}{Mo}$, $C3 = \frac{\left(\frac{1}{C-1}\right)^K}{Mo}$

Quadratic equation: $y = ax^2 + bx + c$

Comparing both equations,

$K = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, $G = \left(\frac{b}{KC}\right) + 2$, $M_o = \frac{1}{CKG}$

Using these, monolayer moisture content was calculated.

3.2.3 Functional and Reconstititional Properties

3.2.3.1 Water Activity

It was measured by using dew point activity meter (Model: Aqualab Series 3 TE, Decagon Devices, USA). Firstly, the instrument was calibrated by placing dry charcoal into the sample disc to absorb the internal moisture of the chamber. The sample was then transferred to the sample disc carefully by not filling it more than half of the volume and immediately to avoid any moisture gain. The tray was placed in the instrument and the chamber was sealed until it reached a particular temperature of 25°C, followed by a blinking light or sound that showed that the process was completed. The value displayed on the instrument was noted as the water activity of the sample.

3.2.3.2 Foaming Properties

It was determined according to the method of De Wit *et al.* (1988) as reported by Shilpashree *et al.* (2015). Phosphate buffer solution (0.05 mol/L, 2.04 g monosodium phosphate and 5.68 g of dipotassium phosphate in distilled water, volume was made upto 1 litre) was made and pH adjusted to 7 with 0.1 N HCl. Hundred ml of 0.05 mol/L phosphate buffer (pH 7) containing 3 g of protein solution was prepared. It was first mixed using a magnetic stirrer for 45 min, followed by mixing in an automix blender at its maximum speed for exactly 6 minutes. The sample was then transferred immediately into a graduated measuring cylinder. Foam capacity was calculated as follows:

Foam capacity (%) = $\frac{B-A}{A} \times 100$

where, A= volume of liquid before whipping (ml)

B = total volume (foam plus liquid) obtained immediately after whipping (ml).

Foam stability was expressed as the volume of foam that remained after keeping the measuring cylinder at 30 ± 2 °C for 30 min, expressed as a percentage of the initial foam volume.

3.2.3.3 Wettability

It was determined by the method of Muers and House (1962) with some modifications. A piece of satin fabric (10×10 cm²) satin of 221.6 g/cm² with about 28 threads per cm² and 90 in the depth was stretched and applied on a metallic can of 6.5 cm diameter and 4.5 cm height, open at both ends. The cloth was held tightly with the help of rubber bands. Another can of 5 cm diameter and 7 cm height open at both ends was placed at spacer to hold it centrally on a large diameter block. A tray of 21.2x16.3 cm (length x breadth) was filled with water at 60 ± 2 °C instead of 40°C, till the mark of 2.5 cm depth. Three glass rods of 0.4 cm thickness and about 8 cm length were placed to form a triangle and the can was placed over it to prevent close contact of cloth with the bottom of the tray. One g of powder was transferred to inner can and was spread in the 5 cm circle using a glass rod as evenly as possible. Inner can was removed and outer can was lowered to glass triangle and held till all powder got wet. The time that elapsed between putting the disc into the water and particles getting wet was measured as wettability in seconds. The mean of three replicates was taken as wetting time.

3.2.3.4 Sinkability

Sinkability was calculated by measuring absorbance using spectrophotometer (Beckman Coulter DU 720 General Purpose UV/Vis Spectrophotometer, USA) calibrated at 760 nm. The cuvette was filled half with distilled water for setting transmittance set as blank. Ten mg of the sample was taken in the cuvette already containing 3.5 ml of distilled water and was tapped 6 times before inserting in the spectrophotometer. Transmittance was measured 3-4 times with intermittent tapping at 0, 2, 4 and 6 minutes intervals. The average of all the transmittance was recorded as the measure of sinkability.

3.2.3.5 Dispersibility

Dispersibility was measured according to the method described by the American Dry Milk Institute (ADMI, 1965). A brass bowl of 13 cm height, top diameter 14 cm, inner diameter 24 cm fitted with an outlet at bottom of 1.25 cm diameter attached with rubber tube with a pinch cork was clamped on a stand, which allowed it to be raised or lowered. Four hundred ml water at about 40 °C was transferred into a bowl. Fifty six g powder was weighed and poured into the bowl. A high shear mixer with blades was fixed in a position at the center of the bowl. It was lowered and operated at 400 rpm for 90 s. The pinch cork at the bottom was opened to release the contents through a standard 72 mesh sieve. The filtrate was collected in a vessel and volume was made to 500 ml with distilled water. Ten ml was taken out in triplicate from the dilution and transferred in pre-weighed aluminium dish and weight of the sample was noted. Weight of solids was determined by keeping in oven at 100±2°C for 2-3 h. Final weight was multiplied with 50 to obtain the dispersibility in grams. Dispersibility in percent was calculated as follows:

$$\% \text{ Dispersibility} = \frac{\text{Dispersibility in g} \times 100}{56}$$

3.2.3.6 Bulk density

For the determination of bulk density, powder sample was filled in 100 ml of measuring cylinder and weight of the powder was recorded. Weight and volume of powder was manually entered in the Tap density meter (Tap Density meter TB 1025, Labindia Analytical Instruments Pvt. Ltd., India). The cylinder was tapped to remove the powder sticking on the wall to obtain the value of bulk density.

$$\text{Bulk Density} = m/V \text{ (kg/m}^3\text{)}$$

where m = mass

V = apparent (tapped) volume V of the powder

3.2.3.7 Tapped density

It was measured by the Tap Density meter (Tap Density meter TB 1025, Labindia Analytical Instruments Pvt. Ltd., India). Fifty ml of powder was filled in a 100 ml measuring cylinder and the weight was recorded. The measuring cylinder was fitted in the tap density meter. Weight and

volume of the powder was entered manually in the apparatus. The equipment was started and cylinder was tapped till the count of 120 from 14 mm height by rotating and tapping simultaneously allowing the material to be evenly packed. Tapping of the cylinder was carried out in three rounds by simultaneous entering of the volume manually. At the end of the process, tapped density was displayed.

$$\text{Tapped Density} = \frac{\text{Weight of powder}}{\text{Final volume of powder}}$$

3.2.3.8 Carr index

$$\text{Carr Index (C)} = \frac{\text{Tapped density } (\rho_T) - \text{Bulk density } (\rho_B)}{\text{Tapped density } (\rho_T)} \times 100$$

3.2.3.9 Hausner ratio

$$\text{Hausner ratio (HR)} = \frac{\text{Tapped density } (\rho_T)}{\text{Bulk density } (\rho_B)}$$

3.2.3.10 True density

It was measured by the method given by Schuck et al. (2012). One g of the powder was transferred to a measuring cylinder. Further, 5 ml of petroleum ether was added and mixed thoroughly with the powder by shaking. Further, one ml of petroleum ether was added to wash the walls of the cylinder. Final volume (powder + petroleum ether) of the sample was recorded. Particle density was calculated as:

$$\text{PD (g/ml)} = \frac{\text{Weight of the powder (g)}}{\text{Volume of (powder+petroleum ether)-6}}$$

3.2.3.11 Peroxide value

Peroxide value was measured by the method adopted in AOAC (2003). Analysis was conducted in artificial light shielded from direct light source. All reagents were prepared fresh. Acetic acid-chloroform mixture was prepared by mixing glacial acetic acid and chloroform in the ratio 3:2. To prepare 0.1 N KI solution, 40 g KI was dissolved in purified water and upon reaching room temperature 12.7g of resublimed iodine was added. The volume made upto 1000 ml and the solution stored in dark. One per cent starch solution was prepared by mixing one gram of soluble

starch with enough cold water to make thin paste, followed by addition of freshly boiled water and stirring while boiling for one minute. Sodium thiosulphate solutions (0.1 M and 0.01 M) were prepared. Conical flask (250 ml) was filled with 10 g milk powder and 50 ml hexane, closed tightly and left overnight. The solution was then filtered using filter paper and the solvent was evaporated. One gram of the sample weighed in a tared 250 ml Erlenmeyer flask. Thirty ml CH₃COOH-CHCl₃ mixture was added and swirled to dissolve, followed by 0.5 ml saturated KI solution from pipette and kept for 1 minute with occasional shaking. Further, 30 ml of distilled water was added. The solution was titrated with 0.1 N sodium thiosulphate with vigorous shaking until yellow colour was almost gone. Titration was continued with vigorous shaking after adding 0.5 ml of 1% starch solution to release all I₂ from CHCl₃ layer, until blue colour disappeared. If more than 0.5 ml of 0.1 N Na₂S₂O₃ used, then determination was repeated with 0.01 N Na₂S₂O₃. Blank determination was conducted by the same procedure without adding sample, and subtracted from test portion.

$$\text{Peroxide value (milliequivalent peroxide/kg oil or fat)} = \frac{(b-a)*N*100}{S}$$

where,

a = Reading of milk powder sample (ml)

b = Reading of blank (ml)

S = original weight of milk powder sample and

N = Normality of Na₂S₂O₃ solution.

3.2.3.12 Colour values

Colour of the product was measured by HunterLab Colourflex colourimeter (Hunter Associated Laboratory, Inc., USA). The instrument was first calibrated by using standard black and white tiles. The sample was filled in a glass cup till half of the volume and then covered with the black cap. The color data for all the samples was evaluated in CIE L*, a* and b* color co-ordinates, using a dual beam spectrophotometer in reflectance mode with wavelength ranging from 350 to 750 nm at 25°C. In order to get triplicate values, the cup was rotated each time and the colour values were read. Data was received in terms of L* (lightness ranging from 0 (blackness) to 100 (whiteness), a* (redness with '+' value indicating redness and '-' value greenness) and b* (yellowness with '+' value indicating yellowness and '-' value blueness).

3.2.3.13 Solubility

It was calculated by the method adopted by Anema *et al.*, (2006); Haque *et al.* (2011), with slight modifications. Reconstituted camel milk was prepared by adding 5 g of camel milk powder in 100 ml warm distilled water. The solution was stirred and mixed at room temperature (25±1 °C) for 30 min, using a stirrer (rotor speed 400 rpm). Then, 40 ml of the bulk solution was transferred to the 50 ml falcon centrifuge tubes and centrifuged at 1000 g at 20°C for 10 min in a refrigerated centrifuge (Model No. 2-16PK, Sigma Laboorzcentrifugen GmbH, Germany) with rotor number 12071. After that, the supernatant was transferred to a clean, dried and weighed aluminium dish. It was dried at 102±2 °C to determine the solid content in the supernatant. Further, 3 g of the bulk solution was transferred to the pre-weighed aluminium dish and dried at 102±2°C to determine the total solid content of the bulk solution. Solubility was then calculated by the following formula:

$$\text{Solubility (\%)} = \frac{\text{Solid in supernatant}}{\text{Solid in bulk solution}} \times 100$$

3.2.3.14 Particle Size

Particle size of camel milk powder was determined by laser light-scattering using a Malvern Zetasizer Nano Series Ver 6.30 (Malvern Instruments Ltd., UK). Ten mg of the sample was dissolved in the 10 ml of de-ionized water and mixed. Further concentrations were prepared by dissolving 1000 µl from this concentration in 10 ml of milliQ water and further dissolving 1 ml from that in 10 ml of de-ionized water. The temperature was maintained at 25°C throughout the measurement. The results of particle size distribution were expressed as diameter (nm) vs. intensity (%).

3.2.4 Microbiological Analysis

It was done by the pour plate method provided by International Dairy Federation as detailed in Table 3.2.

3.2.4.1 Preparation of Peptone Water

Twenty gram of buffered HiCynthTM Peptone water was dissolved in 1000 ml of distilled water, transferred to tubes or conical flasks and sterilized by autoclaving at 1.1 kg/cm² pressure (121 °C) for 15 minutes.

Table 3.2 Preparation of agar

Agar	Analysis	Preparation	Dilution
Plate Count Agar	Total plate count	23.5 g in 1000 ml distilled water	10 ³ , 10 ⁴ , 10 ⁵
Violet Red Bile Agar	Coliform	39.5 g in 1000 ml distilled water	10 ¹ , 10 ² , 10 ³
Potato Dextrose Agar	Yeast and Mold	39 g in 1000 ml distilled water	10 ¹ , 10 ² , 10 ³
Starch Agar	Spores	25 g in 1000 ml distilled water	10 ¹ , 10 ² , 10 ³

The prepared agars were then sterilized by autoclaving at 1.1 kg/cm² pressure (121 °C) for 15 minutes.

3.2.4.2 Preparation of Dilution of Sample

Ten gram of the milk powder was dissolved in 90 ml of the sterile diluent (peptone water) to make primary dilution. Then, a series of dilution was prepared to 10⁻⁵ by transferring 1 ml of the primary dilution into test tube containing 9 ml of sterile diluent and operations were repeated using 1 ml of 10⁻² dilution into 9 ml sterile diluent and so on.

3.2.4.3 Total plate count

The total number of viable counts in the camel milk powder was enumerated according to the method provided by IDF (1991). From the prepared dilutions (10⁻³, 10⁻⁴, 10⁻⁴), 1 ml was transferred to the sterile petri plates in duplicates by using dispensing pipette (1000 µl) with sterile microtips. Further, 15 ml of the sterile media (at ~ 45°C) was poured and mixed well in clockwise and anticlockwise direction. The mixture was allowed to solidify and the plates were incubated at 37°C for 72±2 h. the plates containing less than 300 and more than 30 colonies were selected. The result was calculated using the following formula.

$$N = \frac{\Sigma C}{(N1 + 0.1N2)D}$$

where

ΣC = sum of colonies counted on all the plates retained

N1 = No. of plates retained in the first dilution

N2 = No. of plates retained in the second dilution

D = dilution factor corresponding to the first dilution

3.2.4.4 Coliform count

Coliform count was enumerated by the method of BSI (1993). One ml of the 10^{-1} , 10^{-2} , 10^{-3} dilution was transferred to the sterile petri plates through dispensing pipettes (1000 μ l) with sterile microtips. Then, 15 ml of violet red bile agar (at $\sim 45^{\circ}\text{C}$) was poured in the plates and mixed well in clockwise and anticlockwise direction, and allowed to solidify.

The plates were incubated at 37°C for 24 ± 2 h, after which those containing more than 10 and less than 200 colonies were counted. The result was calculated using the formula provided in section 3.2.4.3.

3.2.4.5 Yeast and Mold count

Yeasts and molds count was enumerated according to the method provided by IDF (1990). The prepared test tube (1 ml) of dilution 10^{-1} , 10^{-2} , 10^{-3} was transferred to sterile petri plates through dispensing pipettes (1000 μ l) with sterile microtips. Ten per cent sterile tartaric acid was prepared and added to the potato dextrose agar to adjust its pH to 3.5. 15 ml of potato dextrose agar (at $\sim 45^{\circ}\text{C}$) was poured and allowed to solidify. The plates were then incubated at 25°C for 5 days. Plates containing more than 10 and fewer than 150 colonies were selected and the result was calculated using the formula provided in the section 3.2.4.3.

3.2.4.6 Spore count

Spore count was enumerated according to the method provided by Marshall (1993). Milk powder (10 g) was reconstituted in peptone water diluent (90 ml) and heated at 80°C or 100°C for 10 or 30 minutes to eliminate the vegetative cells. From this primary dilution (10^{-1}), other dilutions were made. One ml of these dilutions (10^{-1} , 10^{-2} , 10^{-3}) were transferred to the sterile petri plates through dispensing pipette (1000 μ l) with sterile microtips. Fifteen ml of starch agar (at $\sim 45^{\circ}\text{C}$) was then transferred to petri plates and mixed in clockwise and anticlockwise direction. The mixture was allowed to solidify and incubated at 45°C for 72 ± 2 h. The plates containing more than 10 or fewer than 200 colonies were selected. The result was calculated using the formula provided in the section 3.2.4.3.

The entire experiment was conducted in aseptic conditions.

3.3 STATISTICAL ANALYSIS

All the analysis were conducted in triplicates and results reported as mean \pm standard error. The data was treated for analysis by analysis of variance (ANOVA), both one way and two-way ANOVA statistically by applying Duncan Post Hoc Test, using SPSS software (Version 26, USA). Results were considered statistically significant at $P < 0.05$.

4. RESULTS AND DISCUSSION

The results of the present investigation entitled “Storage Studies on Spray Dried Camel Milk Powder” are presented in this chapter. It includes moisture sorption phenomenon of spray dried camel milk powder with regard to temperature dependence and isotherm modeling as well as the effect of storage temperature (25°C, 37°C, 45°C) on physicochemical, reconstititional, functional and microbiological parameters of spray dried camel milk powder.

4.1 PROXIMATE COMPOSITION OF CAMEL MILK POWDER

Spray dried camel milk powder prepared at optimized processing conditions by Bharati (2020) was evaluated for its storage stability. The proximate composition of spray dried camel milk powder is presented in Table 4.1.

Table 4.1 Proximate composition (%) of spray dried camel milk powder

S.No.	Parameter	Camel milk powder
1.	Moisture content, %	1.42 ± 0.17
2.	Fat, %	27.86 ± 0.14
3.	Protein, %	26.80 ± 0.52
4.	Ash, %	8.04 ± 0.10
5.	Lactose, %	35.84 ± 0.40

Mean ± SE; n=3

The moisture content of the sample recorded was ~ 1.42 ± 0.17%. Generally, the moisture content of spray dried camel milk powder ranges from 1.01% to 2.41% depending on direction of feed (Sulieman *et al.*, 2014). Fat content of milk increases 9-10 times on drying, which, in the current study was 27.86 ± 0.14%, which was close to the value reported by Deshwal *et al.* (2020). Protein content of the powder was estimated to be 26.80 ± 0.52%, similar to the one presented by Zouari *et al.* (2020b). Ash content of the camel milk powder is generally higher than that of cow milk powder, and was found to be 8.04 ± 0.10%, which is in agreement with studied by Zouari *et al.* (2020b). The value reported by Sulieman *et al.* (2014) ranging from 6.69-7.69%, was lower, while Deshwal *et al.* (2020) reported a higher value (9.27 ± 0.89%). The lactose content was measured as 35.84 ± 0.40%, slightly higher than that observed by Deshwal *et al.* (2020).

Table 4.2 Reconstititional, Functional and Microbiological properties of fresh Spray Dried Camel Milk Powder

S. No.	Properties	Value
1.	Water activity (a_w)	0.13 ± 00
2.	Average Particle Size (nm)	325.17 ± 19.37
3.	Colour L*	86.47 ± 0.05
	a*	-1.90 ± 0.05
	b*	10.85 ± 0.13
4.	Bulk density (g/cm^3)	0.39 ± 0.01
5.	Tapped density (g/cm^3)	0.42 ± 0.01
6.	Carr Index	5.62 ± 0.62
7.	Hausner ratio	1.06 ± 0.01
8.	True density (g/cm^3)	1.19 ± 0.07
9.	Wettability (s)	3.67 ± 0.15
10.	Dispersibility (%)	67.83 ± 0.44
11.	Solubility (%)	98.58 ± 0.13
12.	Sinkability (% transmittance)	88.19 ± 22.83
13.	Foaming capacity (%)	32.16 ± 0.76
14.	Foaming stability (%)	95.84 ± 0.06
15.	Peroxide value (meq/kg oil)	2.22 ± 0.10
16.	Total plate count (log cfu/g)	2.22 ± 0.10
17.	Coliform count (log cfu/g)	1.01 ± 0.01
18.	Yeast and Mold count (log cfu/g)	1.04 ± 0.02
19.	Thermophilic spore count (log cfu/g)	1.13 ± 0.01

Mean \pm SE; n=3

The values given in the Table 4.2 suggest that the freshly prepared spray dried camel milk powder taken for the study had very high solubility, low microbial counts due to reduced water activity, but low foaming properties and dispersibility. Deshwal *et al.* (2020) reported water activity of 0.19 ± 0.01 . Water activity value for our sample maybe low due to lower moisture content. The colour values for our sample are consistent with the values found for freeze dried

camel milk powder as L^* (86.73 ± 3.01), a^* (-1.20 ± 0.18), b^* (10.23 ± 0.33) by Deshwal *et al.* (2020). The values for bulk density, tapped density and Hausner ratio are near the values reported by Sulieman *et al.* (2014) as within the range 0.37-0.41, 0.45-0.53, and 1.21-1.33 respectively. Our values for foaming capacity, true density and dispersibility for spray dried camel milk powder is in accordance with the values mentioned by Bharati, (2020) as 34.34-39.16%, 1.20-1.28 g/cm³ and 64.87-70.65% respectively. Ho *et al.* (2019) calculated the solubility as $98.62 \pm 1.47\%$, similar to our results.

4.2 MOISTURE SORPTION ISOTHERM

The experiments were conducted as specified in the Section (Chapter III). Experimental data of the equilibrium moisture content and water activity obtained at different experimental conditions are presented in Table 4.3. The moisture adsorption behaviour is manifested in the form of sigmoid shaped curves reflecting a Type II isotherm (Brunaue *et al.*, 1938), which is typical to most of the foods.

The isotherms (Fig. 4.1) demonstrate an increase in equilibrium moisture content with increasing water activity, as reported in case of domestic and imported milk powders (Ko *et al.*, 2008). It was observed that the moisture content increases from 1.42 (% d.b.) to 23.50, 18.55 and 14.67 (% d.b.) at 25, 37 and 45°C respectively. Equilibrium moisture content of all the samples was found to be greater at 25°C as compared to 37 °C, and 45°C and was in agreement with Deshwal *et al.* (2020). This is because proteins and carbohydrates have higher water binding capacity at lower temperature (Ko *et al.*, 2008). Moreover, there is more breakage of hydrogen bonds thus separating water molecules at higher temperature (Kumar *et al.*, 2015).

4.2.1 Isotherm Modeling

The values of monolayer moisture content ' M_o ', coefficient of determination ' R^2 ' and GAB constants C and K calculated for camel milk powder at three temperatures 25, 37 and 45°C are given in the Table 4.4. The experimental data on moisture sorption was fitted to two different models using Brunauer, Emmett and Teller (BET) and Guggenheim-Anderson-de Boer (GAB). BET model was found to be best fitted for all the samples in the water activity range of 0.114-0.443 and GAB model over the entire range of water activity (0.114-0.855).

Table 4.3 Equilibrium moisture content (% d.b.) of spray dried camel milk powder at different temperatures and water activities (a_w) for adsorption

Sl. No.	Temperature (° C)	Water Activity (dimensionless)	Relative humidity (%)	EMC (% d.b.)
1	25	0.114	11	2.43
		0.237	23	3.54
		0.328	33	4.54
		0.443	44	5.18
		0.536	53	5.46
		0.658	65	12.18
		0.761	76	12.72
		0.855	85	23.50
2	37	0.114	11	2.28
		0.237	23	3.48
		0.328	33	3.79
		0.443	44	4.44
		0.536	53	5.15
		0.658	65	9.13
		0.761	76	12.99
		0.855	85	18.55
3	45	0.114	11	1.16
		0.237	23	2.34
		0.328	33	2.47
		0.443	44	2.62
		0.536	53	3.15
		0.658	65	8.64
		0.761	76	11.83
		0.855	85	14.67

n=3

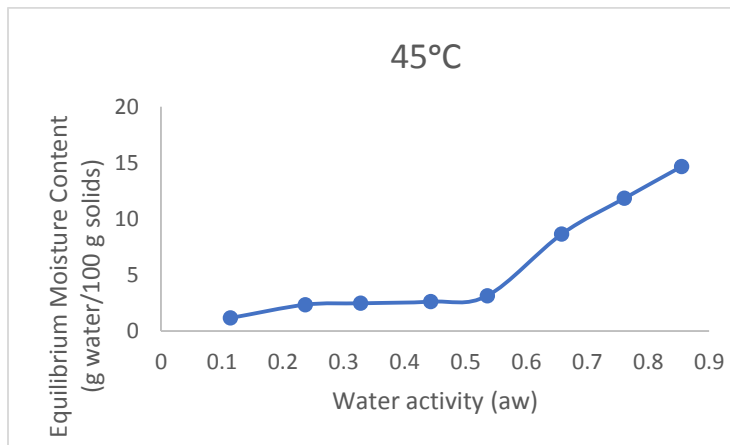
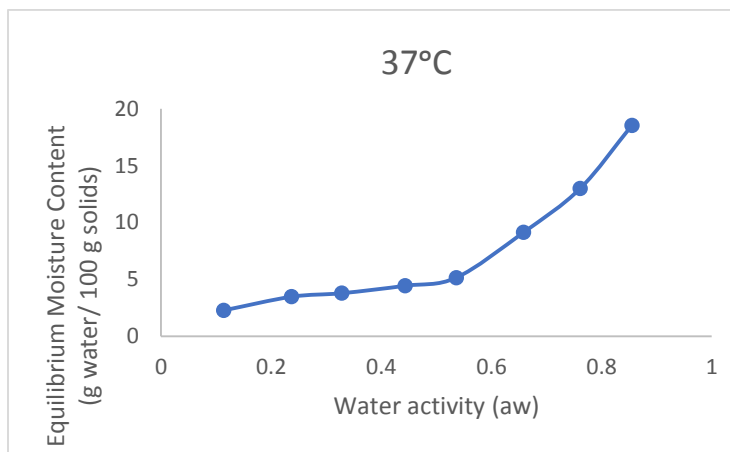
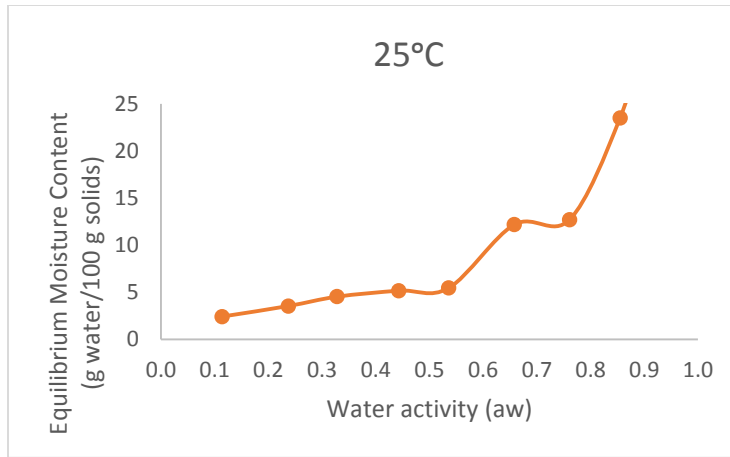


Fig. 4.1. Moisture sorption isotherms of spray dried camel milk powder at 25 °C, 37 °C and 45 °C

Table 4.4 Constants of isotherm models of spray dried camel milk powder

S. No.	Model	Constant	Temperature (°C)		
			25	37	45
1.	BET	M_0	3.17	2.60	1.63
		C	19.02	49.28	30.32
		R^2	0.99	0.99	0.91
2.	GAB	K	1.00	0.98	0.93
		M_0	3.21	2.66	1.77
		C	16.00	31.54	14.93
		R^2	0.84	0.90	0.68

M_0 - Monolayer moisture content; R^2 - Coefficient of determination; C and K are constants related to water binding energy by monolayer and distant sorbed molecules, respectively.

Monolayer moisture content represents the optimum moisture content for storage stability. It represents the moisture content above which water bound to ionic and polar molecules behave as liquid phase (Rizvi, 2014). The results showed that the adsorbed monolayer moisture content of camel milk powder decreased from 3.17 g/100 g solids at 25°C to 2.63 g/100 g at 37°C and 1.63 g/100 g at 45°C, by applying BET model. In the present study, M_0 was found to be similar for both BET and GAB equations for all the samples at given temperatures.

According to Rizvi (2014), M_0 for BET is lower as compared to M_0 for GAB, and $C_{(BET)} > C_{(GAB)}$. In this study, $M_0_{(BET)}$ was calculated to be as 3.17, 2.60, 1.63 and $M_0_{(GAB)}$ as 3.21, 2.66, 1.77 for 25 °C, 37 °C and 45 °C, respectively. Similarly, $C_{(BET)}$ was measured as 19.02, 49.28, 30.32, while $C_{(GAB)}$ was 16.00, 31.54, 14.93 for 25 °C, 37 °C and 45 °C, respectively.

McLaughlin and Magee (1998) suggested that monolayer moisture content decreases with the increase in temperature, as reflected in this study. This can be attributed to the structural changes in starch polymers at higher temperatures. On increasing temperature, degree of hydrogen bonding is reduced, thereby decreasing water binding sites and hence monolayer moisture content

(Westgate et al., 1992). At higher temperature, some of the water molecules get activated to energy levels, allowing them to break away from the sorption sites, thus decreasing the equilibrium moisture content (Palipane and Driscoll, 1992). Similar observations were made by Koc *et al.* (2010), who mentioned that monolayer moisture content values (M_0) obtained by the BET model decreases with increasing temperature. Also, the M_0 value obtained by the GAB equation was higher than that obtained by the BET model. Basu et al. (2006) also reported that the M_0 value given by the BET isotherms is always lower than the monolayer value derived from GAB isotherm. High M_0 values may be due to considerably high sorption capacity through the swelling of colloidal material, thereby increasing the number of polar sites.

Although at 25 °C, monolayer moisture content found in the present study is higher than the findings of Deshwal *et al.* (2020), who reported M_0 for spray dried camel milk powder using BET equation at 25 °C to be 2.284 g/100 g and using GAB equation to be 2.401 g/100 g.

4.3 ASSESSMENT OF PHYSICOCHEMICAL, RECONSTITUTIONAL, FUNCTIONAL AND MICROBIAL CHANGES IN SPRAY- DRIED CAMEL MILK POWDER DURING STORAGE

Representative samples of camel milk powder packaged in metal laminates were taken out from different storage conditions (25 °C, 37 °C and 45 °C) at regular intervals (once in 20 days) and analyzed for physicochemical properties (a_w , moisture content, color, loose bulk density, tapped bulk density, true density, Hausner ratio and Carr's index, peroxide value), functional properties (foaming capacity, foaming stability), reconstititional properties (solubility, wettability dispersibility, sinkability), and microbiological properties (total plate count, coliform count, yeast and mold count, spore count).

4.3.1 Effect of Storage Period and Temperature on the Moisture Content of the Spray Dried Camel Milk Powder

Moisture content of the powder is an important parameter, and increase in moisture is mostly detrimental to powder performance though, in some applications it can have positive effects such as increased flowability due to lubrication, or for electrostatically charged powder it can provide a conductive path for charge to dissipate (Armstrong *et al.*, 2014). Fitzpatrick *et al.* (2007a) showed that the food powders having higher amount of amorphous lactose absorbs more moisture giving rise to lumping and caking problems.

Moisture content of the spray dried camel milk powder in the current study increased significantly ($P < 0.05$) with storage period at all temperatures. Powder stored at 25 °C showed higher increase in moisture content. Change in moisture content decreased with increase in temperature. There was no significant increase in moisture content in the first 20 days of storage. The moisture content obtained at 25 °C throughout the storage period, were significantly different than those at 37 °C and 45 °C. But, no statistically significant difference ($P > 0.05$) was noticed between the moisture content at 37 °C and 45 °C throughout the defined period of storage. Moisture content of the powder on the zero day was $1.42 \pm 0.17\%$, which increased significantly ($P < 0.05$) at the end of 120 days to 2.95 ± 0.21 , 2.67 ± 0.07 and $2.34 \pm 0.34\%$ at 25, 37 and 45 °C, respectively, at the end of 120 days. A non-significant ($P > 0.05$) interaction effect of storage period and temperature was noticed on the moisture content. Moisture content of powder sample throughout the storage is presented in Table 4.5 and Fig 4.2. Uzzaman *et al.* (2018) reported that moisture content of tilapia powder increased with storage period and moisture absorption was lower at higher temperature. This might be due to lower relative humidity obtained at higher temperature (SCIENCING, 2018). As a result, moisture is absorbed but at a lower rate as compared to lower storage temperatures.

Table 4.5. Effect of storage period and temperature on the moisture content (%) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	1.42 ± 0.17^{aD}	1.42 ± 0.17^{aE}	1.42 ± 0.17^{aB}
2	20	1.89 ± 0.11^{aC}	1.60 ± 0.15^{aDE}	1.44 ± 0.18^{aB}
3	40	2.03 ± 0.14^{aBC}	1.88 ± 0.06^{aCD}	1.68 ± 0.10^{aB}
4	60	2.17 ± 0.10^{aBC}	1.94 ± 0.03^{abBC}	1.78 ± 0.07^{cB}
5	80	2.24 ± 0.05^{aBC}	2.04 ± 0.10^{abBC}	1.93 ± 0.01^{cAB}
6	100	2.43 ± 0.19^{aB}	2.22 ± 0.02^{abB}	1.97 ± 0.03^{cAB}
7	120	2.95 ± 0.21^{aA}	2.67 ± 0.07^{aA}	2.39 ± 0.34^{aA}

Mean \pm SE; n=3; values with different superscripts within a row (a-c) and column (A-E) differ significantly ($P < 0.05$).

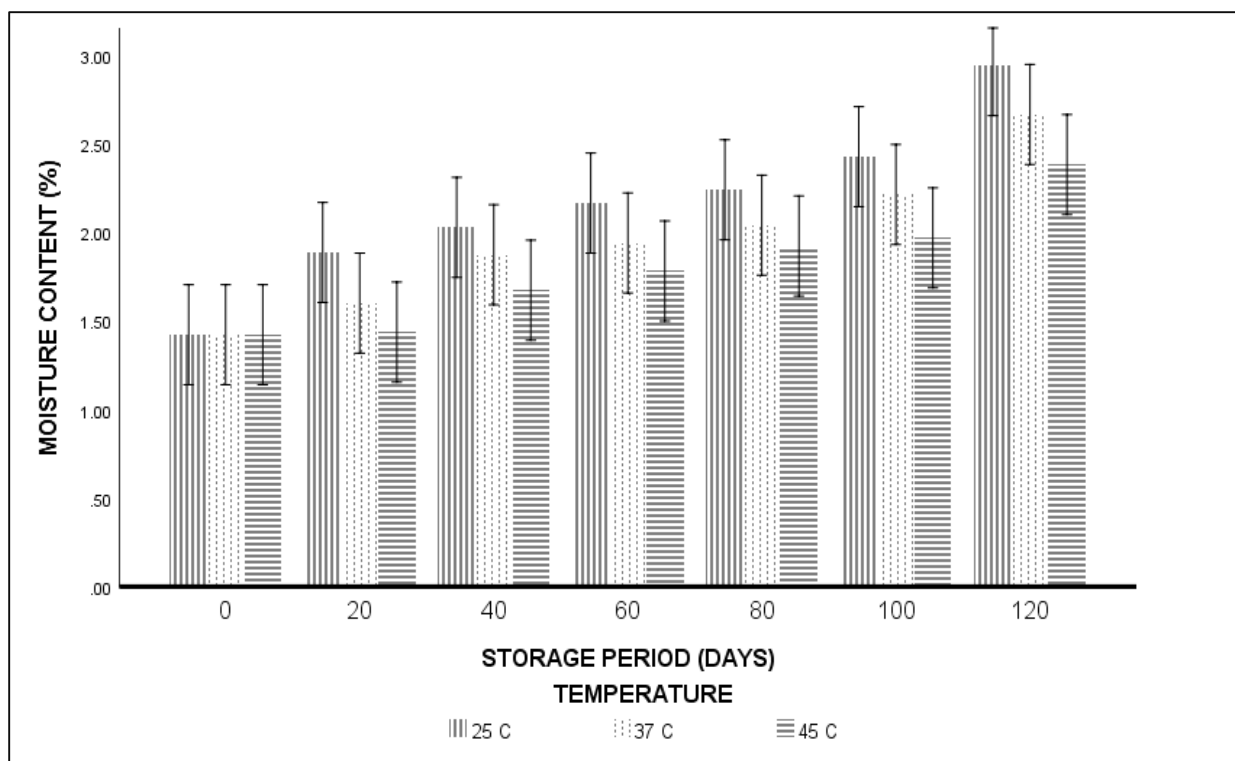


Fig. 4.2 Effect of storage period and temperature on moisture content of the spray dried camel milk powder

During storage, dried milk powders either absorb the moisture or loose it depending on the humidity of the surroundings. This process is continued until an equilibrium is attained between the powder and the surrounding atmosphere (Ho *et al.*, 2019).

4.3.2 Effect of Storage Period and Temperature on the Water Activity of the Spray Dried Camel Milk Powder

Water activity of the camel milk powder sample throughout the storage period is presented in Table 4.6 and Fig. 4.3. Shelf life of the product is related to the water activity and higher storage stability can be attributed to lower water activity. At zero-day, water activity of the powder sample was recorded as 0.13, which increased significantly ($P < 0.05$) to 0.27 ± 0.00 , 0.17 ± 0.00 and 0.15 ± 0.00 at 25, 37 and 45 °C, respectively, at the end of 120 days. Water activity of the sample increased with storage period till 40 days in a statistically significant ($P < 0.05$) manner. It dropped a little and then again increased. The permeability of the packaging material affects the moisture content and water activity of the powder.

Table 4.6 Effect of storage period and temperature on the water activity of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	0.13 ± 0.00 ^{aC}	0.13 ± 0.00 ^{aE}	0.13 ± 0.00 ^{aC}
2	20	0.15 ± 0.00 ^{aC}	0.14 ± 0.00 ^{aDE}	0.14 ± 0.00 ^{aBC}
3	40	0.21 ± 0.01 ^{aB}	0.18 ± 0.01 ^{aB}	0.17 ± 0.00 ^{aA}
4	60	0.23 ± 0.01 ^{aB}	0.16 ± 0.01 ^{bBC}	0.13 ± 0.00 ^{bC}
5	80	0.26 ± 0.01 ^{aB}	0.20 ± 0.00 ^{bA}	0.17 ± 0.01 ^{bA}
6	100	0.22 ± 0.01 ^{aA}	0.16 ± 0.01 ^{bCD}	0.13 ± 0.00 ^{cC}
7	120	0.27 ± 0.00 ^{aA}	0.17 ± 0.00 ^{bBC}	0.15 ± 0.00 ^{cB}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-D) differ significantly (P < 0.05).

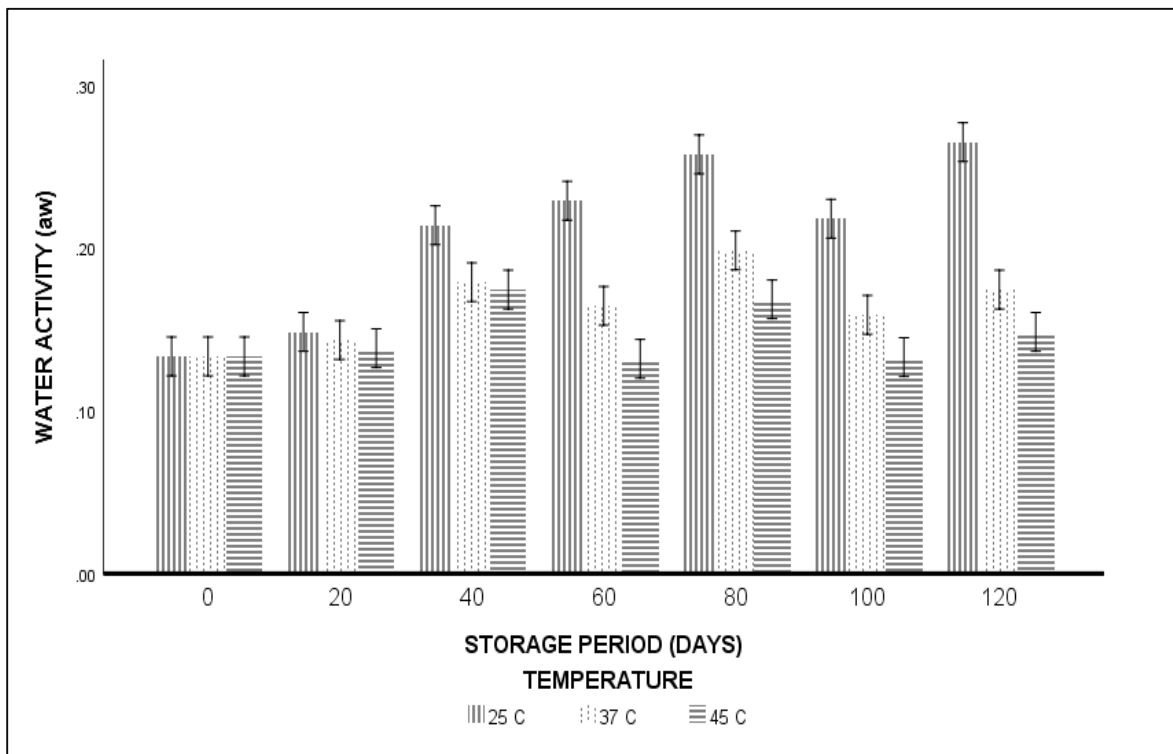


Fig. 4.3. Effect of storage period and temperature on water activity of the spray dried camel milk powder

At different temperatures, water activity was found to differ significantly ($P < 0.05$). A significant ($P < 0.05$) interaction effect of storage period and temperature was found on the values of water activity. Water activity is a thermodynamic term related to chemical potential of water. At low water activity, deteriorative reactions are less, but some changes may occur during storage such as fat oxidation and non-enzymatic browning, which may change the availability of the moisture in the powder. Water is released during the initial stages of Maillard reaction, while it is consumed later in the reaction (Bell, 2007). However, all the values remained at ~ 0.2 , indicating little chance of microbial growth for camel milk powder sample during the 4 months of storage period under study, suggesting higher stability. The rate of change in the physical, and functional (caking, solubility, browning) properties depends on water activity of the milk powder. According to Ostbring *et al.* (2020), powders display high water activity at higher relative humidity. This might be the reason that water activity decreased at higher temperature from 25 °C to 37 and 45 °C. These results are consistent with that of the moisture content due to the process of vapour transmission through packaging material. Water activity is considered as a better indicator of food quality as well as shelf life of the product than moisture content (Li *et al.*, 2017).

4.3.3 Effect of Storage Period and Temperature on the Colour L* value of the Spray Dried Camel Milk Powder

The lightness (L*) values of the spray dried camel milk powder are reported in the Table 4.7 and Fig. 4.4. The results indicated that at all the temperatures lightness decreased significantly ($P < 0.05$) during the storage. Although, this reduction in L* value was negligible from 86.47 ± 0.05 to 85.64 ± 0.04 and 84.97 ± 0.05 at 25 °C and at 37 °C respectively, it decreased slightly to 83.76 ± 0.04 at 45 °C, at the end of 120 days. Among the values obtained at different temperatures, there was a significant ($P < 0.05$) difference observed. The storage period and temperature interacted in a significant ($P < 0.05$) manner. Lightness values are mostly affected by the physicochemical and microbiological changes occurring in the powder. Least changes observed might be due to the collective effects of oxidation, Maillard browning and crystallization of lactose.

Table 4.7 Effect of storage period and temperature on the L* value of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	86.47 ± 0.05 ^{aA}	86.47 ± 0.05 ^{aA}	86.47 ± 0.00 ^{aA}
2	20	86.34 ± 0.10 ^{aA}	85.73 ± 0.09 ^{bB}	84.90 ± 0.02 ^{cB}
3	40	86.34 ± 0.08 ^{aA}	85.19 ± 0.06 ^{bC}	83.73 ± 0.03 ^{cC}
4	60	86.33 ± 0.01 ^{aA}	85.13 ± 0.08 ^{bC}	84.36 ± 0.03 ^{bD}
5	80	85.76 ± 0.02 ^{aB}	85.09 ± 0.39 ^{abC}	84.34 ± 0.06 ^{bD}
6	100	85.65 ± 0.05 ^{aB}	85.07 ± 0.01 ^{bC}	83.44 ± 0.10 ^{cE}
7	120	85.64 ± 0.04 ^{aB}	84.97 ± 0.05 ^{bC}	83.76 ± 0.04 ^{cF}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-F) differ significantly (P < 0.05)

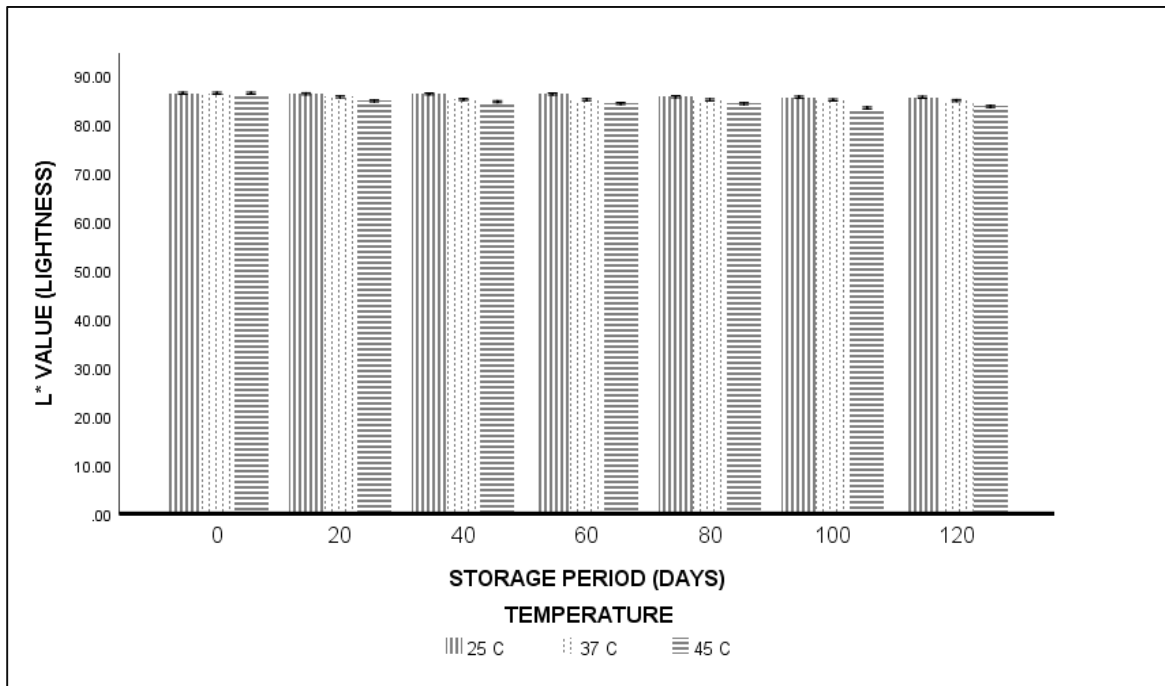


Fig. 4.4 Effect of storage period and temperature on L* value of the spray dried camel milk powder

These results are in accordance with Uzzaman et al. (2018), who reported that the L* value decreased gradually ($P < 0.05$) when stored at ambient as well as at the elevated temperatures and the lowest value was recorded at the highest storage temperature. Ostbring *et al.* (2020) also mentioned that L* value decreased significantly during storage. Similar results were found by Kristanti and Herminiati (2021). They further reported that the factors affecting the lightness during storage of a food product are packaging material, sugar and protein content of product, water activity, storage time.

4.3.4 Effect of Storage Period and Temperature on the Colour a* value of the Spray Dried Camel Milk Powder

a* values of the spray dried camel milk powder throughout the storage is presented in the Table 4.8 and Fig. 4.5. The a* value was negative, which indicated greenness. Further, it decreased significantly ($P < 0.05$) as storage proceeded. There was also a significant ($P < 0.05$) difference between the values obtained at different temperatures. Also, greenness reduced more prominently at higher storage temperature. A significant ($P < 0.05$) interaction between storage period and temperature was noticed.

Table 4.8 Effect of storage period and temperature on a* value of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	-1.90 ± 0.05 ^{aC}	-1.90 ± 0.05 ^{aB}	-1.90 ± 0.05 ^{aC}
2	20	-2.12 ± 0.01 ^{bD}	-1.93 ± 0.02 ^{aB}	-1.94 ± 0.03 ^{aC}
3	40	-2.12 ± 0.01 ^{cD}	-1.55 ± 0.02 ^{bAB}	-1.03 ± 0.06 ^{aB}
4	60	-1.37 ± 0.02 ^{bA}	-1.53 ± 0.17 ^{bAB}	-0.91 ± 0.04 ^{aB}
5	80	-1.61 ± 0.06 ^{aB}	-1.31 ± 0.22 ^{aA}	-0.91 ± 0.01 ^{aB}
6	100	-1.71 ± 0.04 ^{cB}	-1.22 ± 0.04 ^{bA}	-0.86 ± 0.15 ^{aB}
7	120	-1.40 ± 0.00 ^{bA}	-1.15 ± 0.18 ^{bA}	-0.40 ± 0.02 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a-b) and column (A-D) differ significantly ($P < 0.05$).

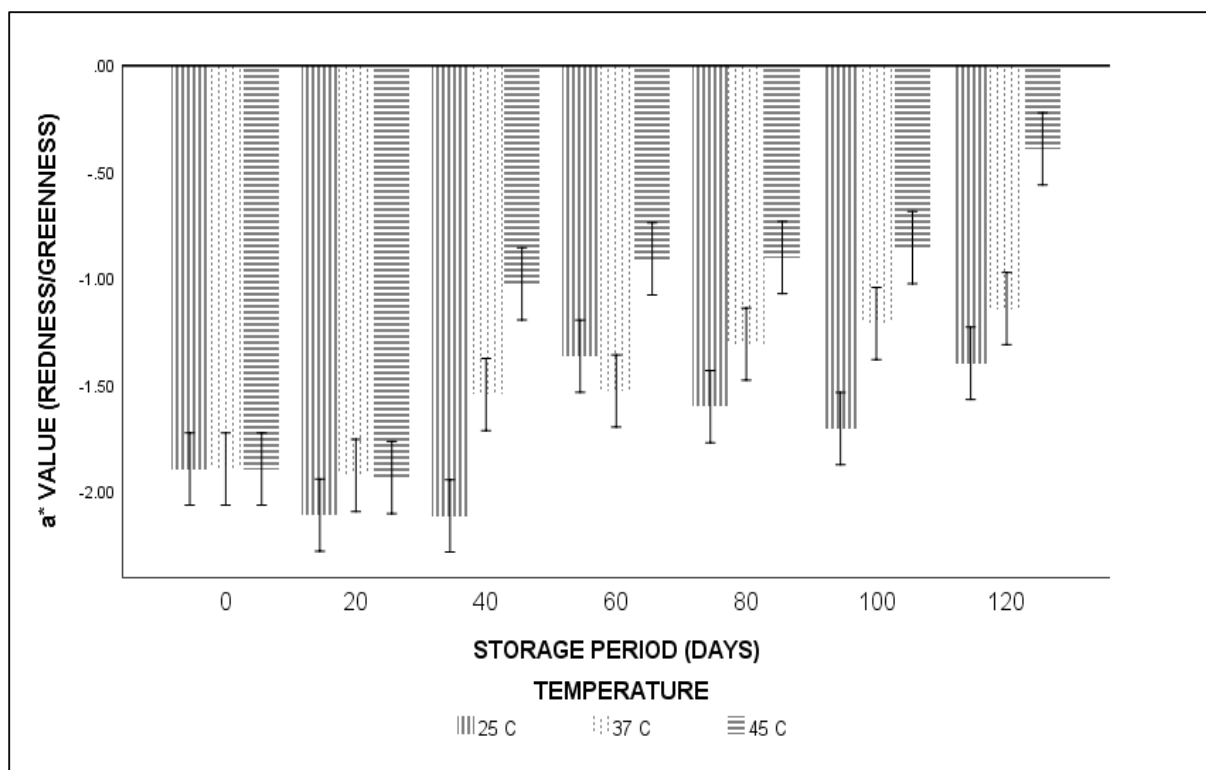


Fig. 4.5 Effect of storage period and temperature on a* value of the spray dried camel milk powder

The fresh spray dried camel milk powder had an a* value of -1.9 ± 0.05 which decreased to -1.40 ± 0.00 , -1.15 ± 0.18 and -0.40 ± 0.02 at 25, 37 and 45 °C, respectively at the end of 120 days. As a* value gives change in colour varying from red and green, it indicates physicochemical changes in the powder. As the temperature increases, the physicochemical properties related to powder also changes. Cesa *et al.* (2015) depicted similar results as storage period increases, a* value becomes less negative.

4.3.5 Effect of Storage Period and Temperature on the Colour b* value of the Spray Dried Camel Milk Powder

The b* value of the spray dried camel milk powder throughout the storage is presented in the Table 4.9 and Fig. 4.6. The b* value of the sample varied between 10.85 to 20.72. As b* value indicates yellowness (+) or blueness (-) of milk powder, there is a significant ($P < 0.05$) increase in the yellowness of the powder with the storage period. This could be owing to the presence of burnt particles. There was a significant ($P < 0.05$) difference observed for the values observed for different temperatures.

Table 4.9 Effect of storage period and temperature on b* value of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	10.85 ± 0.13 ^{aG}	10.85 ± 0.13 ^{aE}	10.85 ± 0.13 ^{aE}
2	20	11.34 ± 0.03 ^{cF}	14.26 ± 0.03 ^{bD}	17.59 ± 0.02 ^{aD}
3	40	13.12 ± 0.04 ^{cE}	15.60 ± 0.03 ^{bCD}	19.11 ± 0.15 ^{aC}
4	60	15.24 ± 0.04 ^{cB}	19.83 ± 0.10 ^{bA}	22.14 ± 0.09 ^{aA}
5	80	14.13 ± 0.04 ^{cD}	16.36 ± 1.15 ^{abC}	18.00 ± 0.05 ^{aD}
6	100	14.61 ± 0.03 ^{cC}	16.50 ± 0.06 ^{bC}	20.54 ± 0.33 ^{aB}
7	120	16.29 ± 0.02 ^{cA}	18.21 ± 0.17 ^{bB}	20.72 ± 0.03 ^{aB}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-G) differ significantly (P < 0.05).

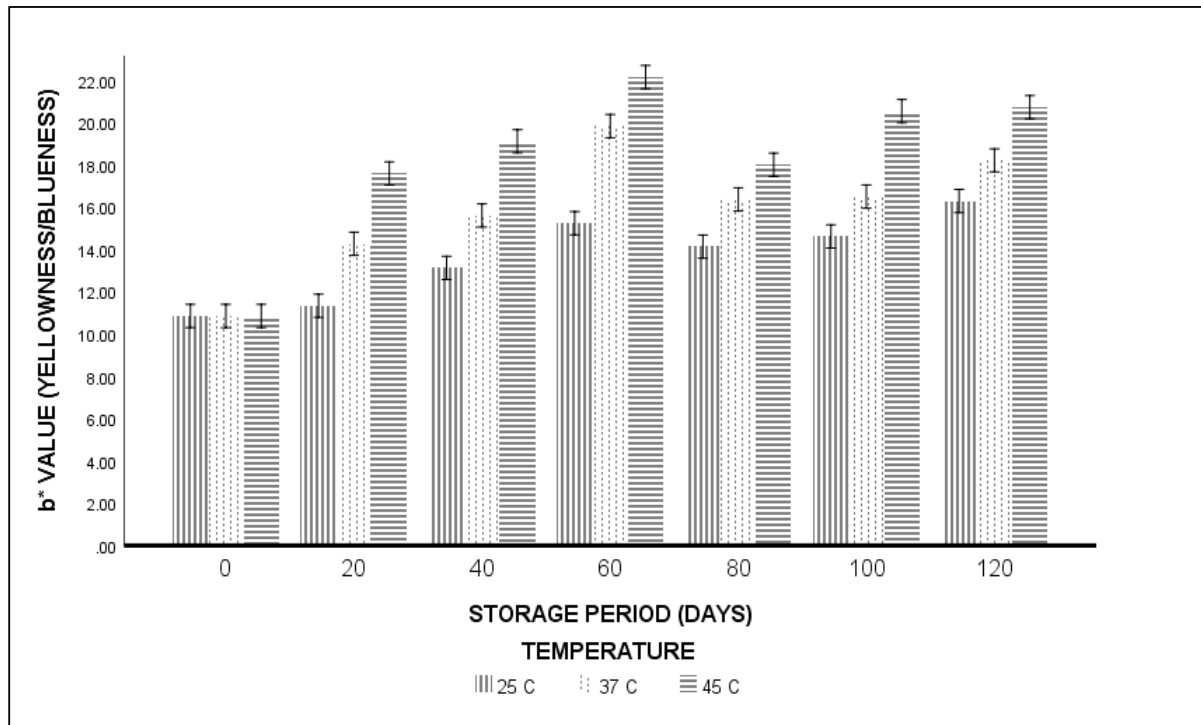


Fig. 4.6 Effect of storage period and temperature on b* value of the spray dried camel milk powder

The colour of powder stored at higher temperature changed more profoundly. Ho *et al.* (2019) observed increase in the b* value on storage of spray dried camel milk powder. A significant ($P < 0.05$) interaction of storage period and temperature was observed for the b* value obtained. Browning of milk powder occurs due to non-enzymatic browning reactions between amino group of lysine and carbonyl group of lactose. It was also reported that colour changes during storage is a result of lactose crystallization and migration of free fat to the surface of powder (Chudy *et al.*, 2015). Likewise, for infant formulas b* value increases with storage period (Cesa *et al.*, 2015).

4.3.6 Effect of Storage Period and Temperature on the Bulk Density of the Spray Dried Camel Milk Powder

Bulk density is a valuable physical property, on which the packaging requirement and material handling of the powder is dependent (Adebowale *et al.*, 2012). The values for bulk density throughout the storage have been given in the Table 4.10 and Fig. 4.7. The results indicate that the bulk density decreased significantly ($P < 0.05$) over the entire period of storage.

Table 4.10 Effect of storage period and temperature on bulk density (g/cm^3) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	0.39 ± 0.01 ^{aA}	0.39 ± 0.01 ^{aA}	0.39 ± 0.01 ^{aA}
2	20	0.39 ± 0.00 ^{aA}	0.39 ± 0.00 ^{aA}	0.39 ± 0.01 ^{aAB}
3	40	0.38 ± 0.00 ^{aAB}	0.38 ± 0.00 ^{aB}	0.38 ± 0.01 ^{aAB}
4	60	0.38 ± 0.01 ^{aBC}	0.37 ± 0.00 ^{aC}	0.37 ± 0.01 ^{aBC}
5	80	0.37 ± 0.01 ^{aCD}	0.36 ± 0.00 ^{aD}	0.36 ± 0.01 ^{aCD}
6	100	0.36 ± 0.01 ^{aDE}	0.35 ± 0.00 ^{aE}	0.35 ± 0.01 ^{aCD}
7	120	0.35 ± 0.01 ^{aE}	0.34 ± 0.00 ^{aF}	0.34 ± 0.01 ^{aD}

Mean ± SE; n=3; values with different superscripts within a row (a) and column (A-F) differ significantly ($P < 0.05$).

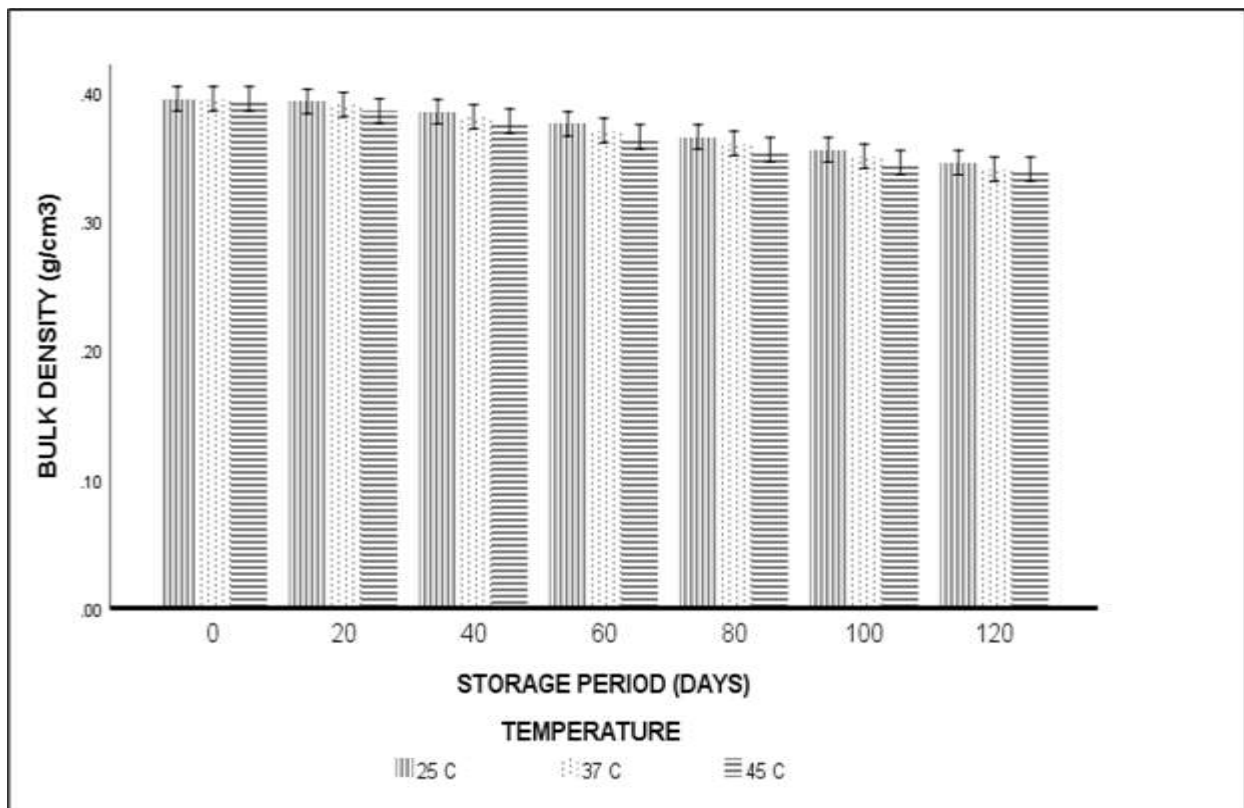


Fig. 4.7 Effect of storage period and temperature on bulk density of spray dried camel milk powder

The bulk density reduced from $0.39 \pm 0.01 \text{ g/cm}^3$ for fresh camel milk powder to 0.35 ± 0.01 , 0.34 ± 0.00 and $0.34 \pm 0.01 \text{ g/cm}^3$ at 25, 37 and 45 °C respectively at the end of 120 days. A significant ($P < 0.05$) difference was observed for bulk density measured at different storage temperatures. This reflects that the decrease in the bulk density is more at higher temperature. Interaction effect of storage period and temperature was non-significant ($P > 0.05$).

Forsido *et al.* (2021) showed that the bulk density of the flour samples decreased significantly with storage period and declined more profoundly at higher temperatures. They explained inverse relation between the bulk density and moisture content. Due to water influx in the sample, mass of the sample increased in a less pronounced manner than expansion of the sample in all the directions (Pradhan *et al.*, 2008). Bulk density is mainly related to powder composition. With the increase in moisture content and decrease in fat content, there is a reduction in bulk density (Kelly *et al.*, 2002; Barbosa-Canovas and Juliano, 2005; Schuck, 2011). With the

increase in the size of particles, porosity increases and free space is formed between them, therefore density decreases (Goula and Adamopoulos, 2005; Kha *et al.*, 2010; Mishra *et al.*, 2014; Santhalakshmy, 2015).

4.3.7 Effect of Storage Period and Temperature on Tapped Density of the Spray Dried Camel Milk Powder

The values for tapped density throughout the storage are presented in the Table 4.11 and Fig 4.8. The decrease in the value of tapped density with the storage period is statistically significant ($P < 0.05$). The value for fresh camel milk powder was determined as $0.42 \pm 0.01 \text{ g/cm}^3$, which reduced to 0.40 ± 0.00 and $0.39 \pm 0.01 \text{ g/cm}^3$ at 25 and 37 °C respectively at the end of storage period of 120 days. The values obtained at different temperatures were significantly ($P < 0.05$) different. A significant ($P < 0.05$) difference between the values obtained at different storage temperature. The interaction effect of storage period and temperature was non-significant ($P > 0.05$).

Table 4.11 Effect of storage period and temperature on tapped density (g/cm^3) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	$0.42 \pm 0.01^{\text{aAC}}$	$0.42 \pm 0.01^{\text{aA}}$	$0.42 \pm 0.01^{\text{aCD}}$
2	20	$0.43 \pm 0.01^{\text{aAB}}$	$0.41 \pm 0.01^{\text{aA}}$	$0.43 \pm 0.01^{\text{aBCD}}$
3	40	$0.43 \pm 0.00^{\text{abAB}}$	$0.41 \pm 0.01^{\text{bA}}$	$0.45 \pm 0.00^{\text{aA}}$
4	60	$0.42 \pm 0.01^{\text{aAB}}$	$0.40 \pm 0.01^{\text{aA}}$	$0.44 \pm 0.00^{\text{aAB}}$
5	80	$0.42 \pm 0.00^{\text{bABC}}$	$0.40 \pm 0.00^{\text{bA}}$	$0.43 \pm 0.01^{\text{aABC}}$
6	100	$0.41 \pm 0.01^{\text{abBC}}$	$0.40 \pm 0.00^{\text{bA}}$	$0.42 \pm 0.00^{\text{aBCD}}$
7	120	$0.40 \pm 0.00^{\text{aC}}$	$0.39 \pm 0.01^{\text{aA}}$	$0.42 \pm 0.00^{\text{aD}}$

Mean \pm SE; n=3; values with different superscripts within a row (a-b) and column (A-D) differ significantly ($P < 0.05$).

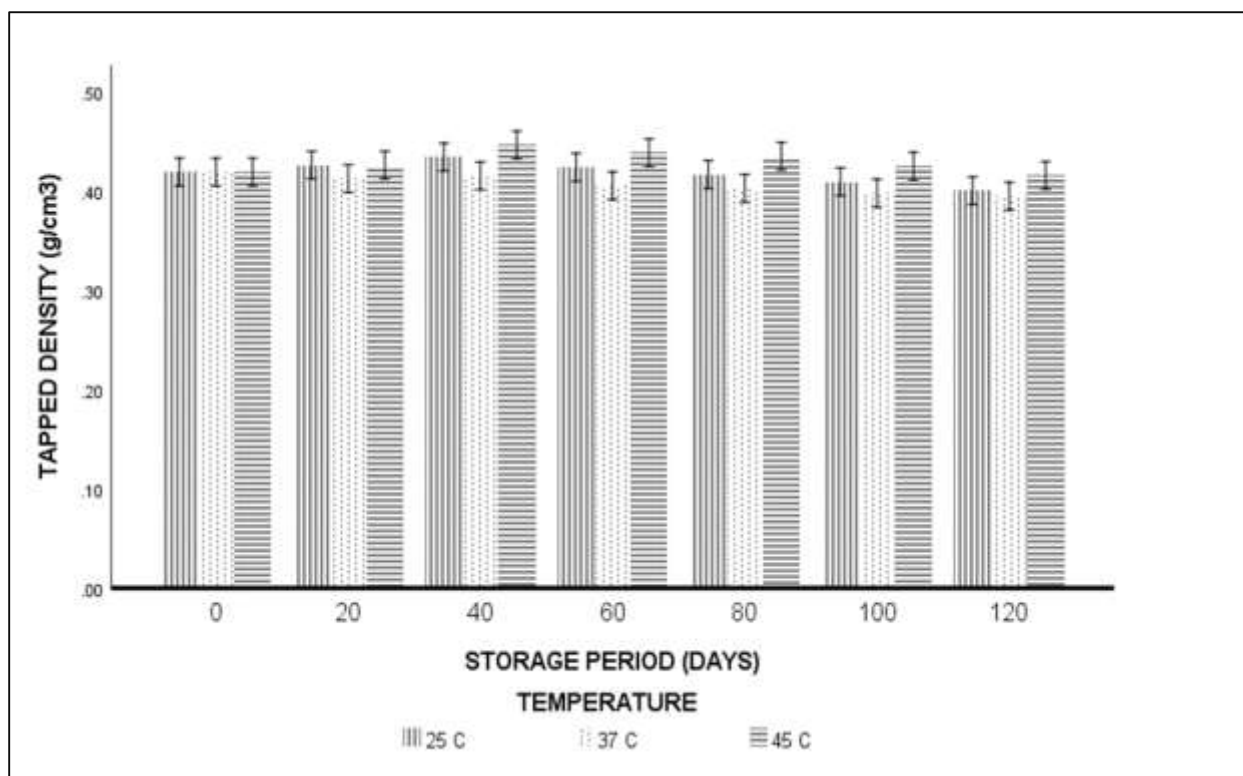


Fig. 4.8 Effect of storage period and temperature on tapped density of spray dried camel milk powder

Tapped density at 45 °C remained nearly constant at the end compared to the fresh powder. Fluctuations in the value were noticed at 25 and 45 °C. At 45 °C, few agglomerates were formed in the powder, which increased particle size. As earlier depicted at lower temperature, more moisture was gained, which caused cohesion resulting in lower tapped density. Erbay and Koca (2015) observed similar fluctuations in the value of tapped density.

4.3.8 Effect of Storage Period and Temperature on the Flowability of the Spray Dried Camel Milk Powder

Flowability is expressed in terms of Carr Index and Hausner ratio. As Carr Index and Hausner ratio increases, flowability of powder decreases. The values for Carr Index and Hausner ratio are tabulated in the Tables 4.12 and 4.13 respectively, while the graphical representations are given in Fig. 4.9 and 4.10, respectively. The result shown here indicates that both Carr Index and Hausner ratio increased significantly ($P < 0.05$) throughout the storage period. A significant ($P < 0.05$)

difference was obtained between the values of both Carr Index and Hausner Ratio at different temperatures. Flowability of the powder reduced after storage at higher temperature. Fresh camel milk powder showed Carr Index and Hausner ratio as 5.61 ± 0.62 and 1.06 ± 0.01 , respectively, indicating excellent flow properties. Carr Index increased to 14.96 ± 0.96 , 13.77 ± 0.73 and 16.91 ± 0.24 at 25, 37 and 45 °C, respectively at the end of 120 days. Similarly, Hausner ratio increased to 1.18 ± 0.01 , 1.16 ± 0.01 and 1.21 ± 0.00 at 25, 37 and 45 °C, respectively at the end of 120 days. A non-significant ($P > 0.05$) interaction effect was observed between storage period and temperature for both Carr Index and Hausner Ratio. Flowability decreases with the increase in surface oil content. Properties of powder particles, like shape, size and density affects the flowability of the powder (Schuck, 2013). Increase in the moisture content make the powder cohesive, which leads to decrease in the flowability. Powders with more amorphous lactose have a tendency to readily absorb moisture from air, resulting in decreased flowability (Fitzpatrick *et al.*, 2007a). This explains the high value of Carr index and Hausner ratio at 25 °C. Rahman *et al.* (2012) reported that melting of fat in freeze dried camel milk powder occurs between 10-29 and 34-46 °C, which further explains the decrease in flowability at 25 and 45 °C.

Table 4.12 Effect of storage period and temperature on Carr Index of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	5.62 ± 0.62^{aB}	5.62 ± 0.62^{aB}	5.62 ± 0.62^{aA}
2	20	8.34 ± 1.67^{aB}	6.50 ± 1.17^{aB}	8.34 ± 1.67^{aA}
3	40	12.38 ± 0.52^{aA}	9.56 ± 1.23^{aAB}	13.64 ± 1.36^{aB}
4	60	12.60 ± 1.06^{aA}	9.77 ± 1.77^{aAB}	14.39 ± 0.44^{aB}
5	80	13.49 ± 0.16^{aA}	11.74 ± 2.06^{aA}	15.99 ± 2.20^{aB}
6	100	14.32 ± 2.04^{aA}	13.15 ± 1.15^{aA}	16.37 ± 1.28^{aB}
7	120	14.96 ± 0.96^{aA}	13.77 ± 0.73^{aA}	16.91 ± 0.24^{aB}

Mean \pm SE; n=3; values with different superscripts within a row (a) and column (A-B) differ significantly ($P < 0.05$).

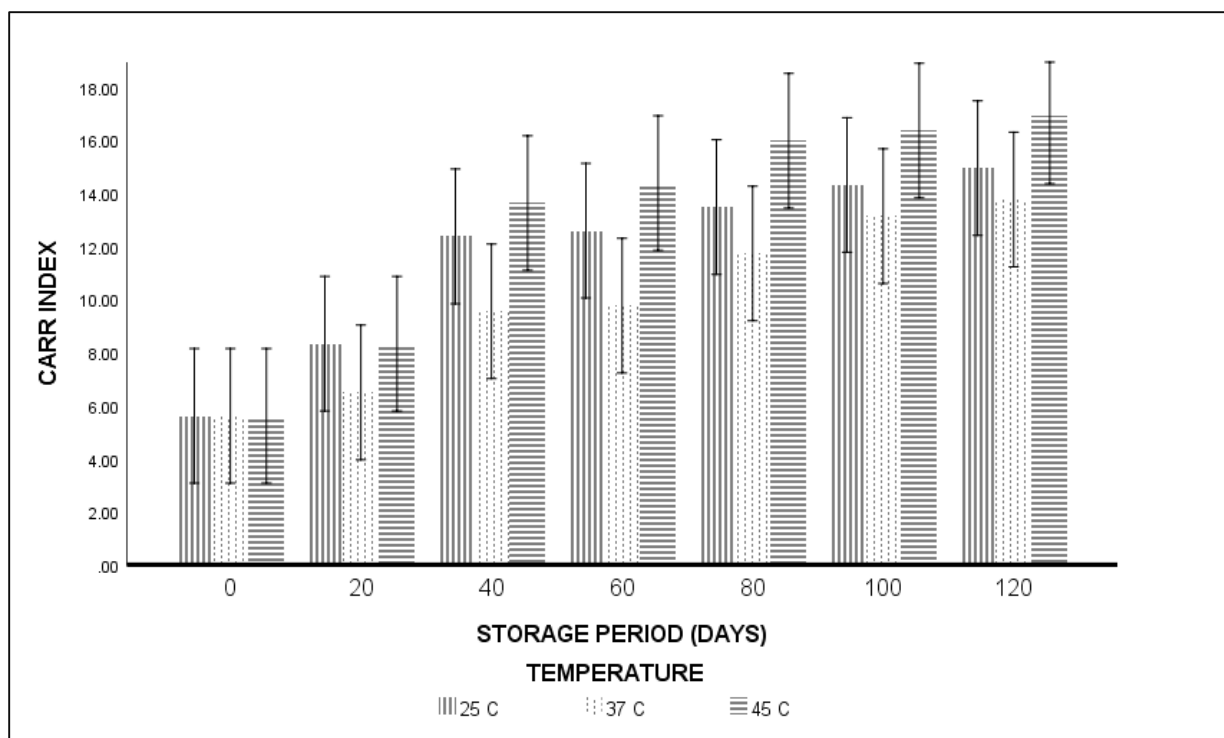


Fig. 4.9 Effect of storage period and temperature on Carr Index of spray dried camel milk powder

Zouari *et al.* (2020b) stated that camel milk powder is rapidly exposed to the surface due to their low mean diameter and exhibit higher fat and lactose proportion in the 5-10 nm of the surface layer. Habtegebriel *et al.* (2018a) determined the glass transition temperature of the spray dried camel milk powder as 38 to 40 °C. According to Fitzpatrick *et al.* (2007b), exposing the powder to 10-20 °C above glass transition temperature renders the powder more sticky. Chauhan and Patil (2013) reported similar results and noted that flowability decreased with increase in storage period as well as the temperature.

Table 4.13 Effect of storage period and temperature on Hausner Ratio of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	1.06 ± 0.01 ^{aC}	1.06 ± 0.01 ^{aB}	1.06 ± 0.01 ^{aB}
2	20	1.09 ± 0.02 ^{aBC}	1.07 ± 0.01 ^{aB}	1.09 ± 0.02 ^{aB}
3	40	1.14 ± 0.01 ^{aAB}	1.11 ± 0.01 ^{aBA}	1.16 ± 0.02 ^{aA}
4	60	1.14 ± 0.01 ^{aAB}	1.11 ± 0.02 ^{aBA}	1.17 ± 0.01 ^{aA}
5	80	1.16 ± 0.00 ^{aA}	1.13 ± 0.03 ^{aA}	1.19 ± 0.03 ^{aA}
6	100	1.17 ± 0.03 ^{aA}	1.15 ± 0.02 ^{aA}	1.20 ± 0.02 ^{aA}
7	120	1.18 ± 0.01 ^{aA}	1.16 ± 0.01 ^{aA}	1.21 ± 0.00 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a) and column (A-C) differ significantly (P < 0.05).

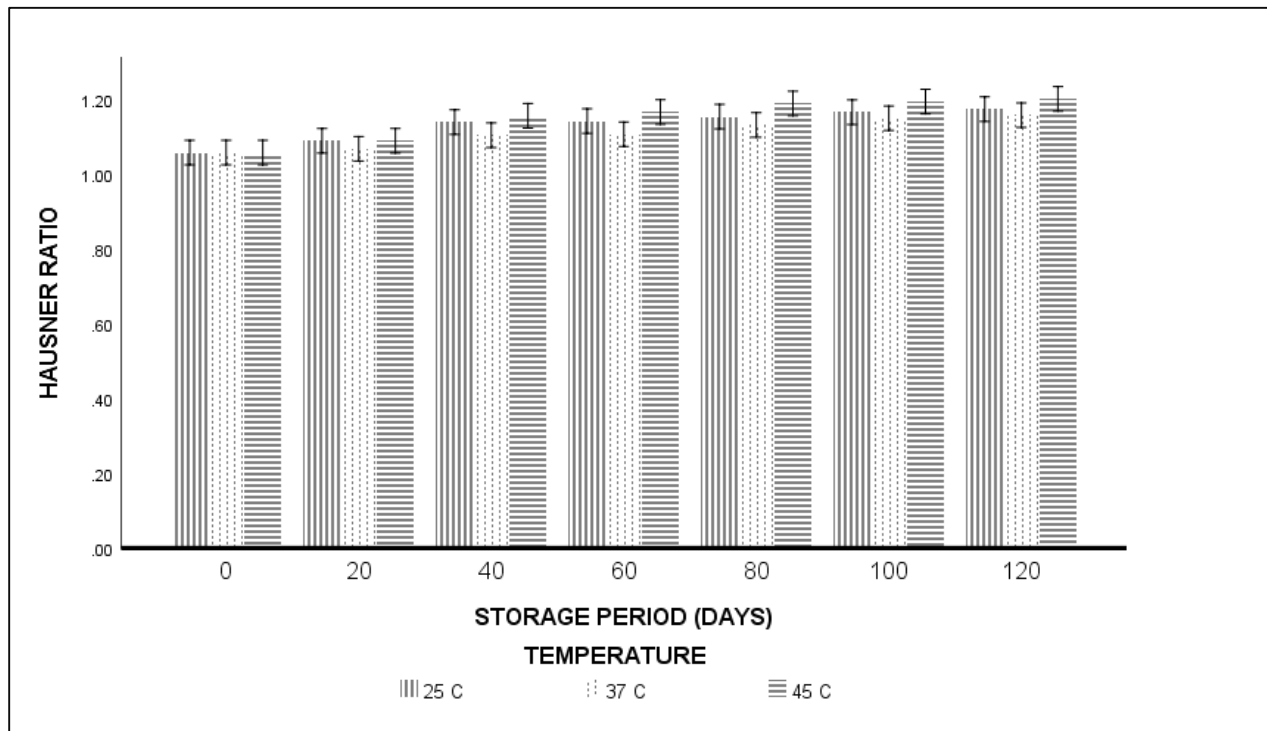


Fig. 4.10 Effect of storage period and temperature on Hausner Ratio of spray dried camel milk powder

4.3.9 Effect of Storage Period and Temperature on True Density of the Spray Dried Camel Milk Powder

The values for true density throughout the storage are shown in the Table 4.14 and Fig. 4.11. The results presented here indicate a significant ($P < 0.05$) decrease in the true density with storage period, but non-significant ($P > 0.05$) difference between the values for different temperatures. For fresh sample, true density was calculated as $1.19 \pm 0.07 \text{ g/cm}^3$, which decreased to 0.91 ± 0.00 , 0.90 ± 0.01 and $0.89 \pm 0.00 \text{ g/cm}^3$ at 25, 37 and 45 °C, respectively at the end of the storage period of 120 days. Non-significant ($P > 0.05$) interaction effect between the storage period and temperature was measured for the values of true density mentioned. True density of the powder is affected by the structure and moisture content of the powder. Crystalline powder is known to have higher true density as compared to amorphous one as atoms in the former are arranged in crystalline lattice at a minimum possible distance from each other, thereby decreasing the volume (Yang *et al.*, 2012). As a result of increase in moisture content, volume of the powder increases at a rate higher than mass, thus causing decrease in true density of the powder (Oginni, 2014).

Table 4.14 Effect of storage period and temperature on true density (g/cm^3) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	$1.19 \pm 0.07^{\text{aA}}$	$1.19 \pm 0.07^{\text{aA}}$	$1.19 \pm 0.07^{\text{aA}}$
2	20	$1.11 \pm 0.03^{\text{aAB}}$	$1.09 \pm 0.03^{\text{aAB}}$	$1.05 \pm 0.05^{\text{aB}}$
3	40	$1.00 \pm 0.00^{\text{aBC}}$	$0.97 \pm 0.06^{\text{aBC}}$	$0.95 \pm 0.03^{\text{aBC}}$
4	60	$0.95 \pm 0.05^{\text{aC}}$	$0.93 \pm 0.02^{\text{aC}}$	$0.90 \pm 0.00^{\text{aC}}$
5	80	$0.92 \pm 0.00^{\text{aC}}$	$0.91 \pm 0.01^{\text{aC}}$	$0.90 \pm 0.00^{\text{aC}}$
6	100	$0.91 \pm 0.01^{\text{aC}}$	$0.90 \pm 0.00^{\text{aC}}$	$0.88 \pm 0.01^{\text{aC}}$
7	120	$0.91 \pm 0.00^{\text{aC}}$	$0.90 \pm 0.01^{\text{aC}}$	$0.89 \pm 0.00^{\text{aC}}$

Mean \pm SE; n=3; values with different superscripts within a row (a) and column (A-C) differ significantly ($P < 0.05$).

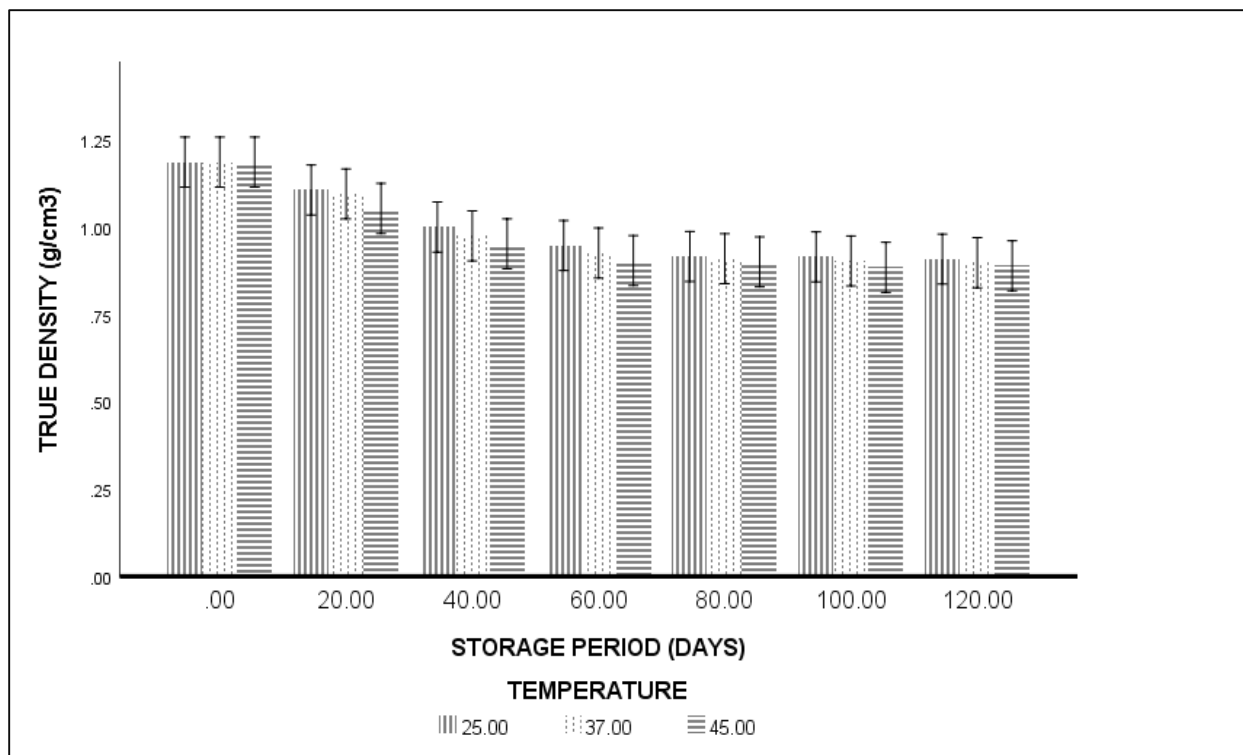


Fig. 4.11 Effect of storage period and temperature on true density of spray dried camel milk powder

4.3.10 Effect of Storage Period and Temperature on the Wettability of the Spray Dried Camel Milk Powder

Wettability of the spray dried camel milk powder throughout the storage is represented in the Table 4.15 and Fig. 4.12. The results mentioned shows that the wettability (i.e., the time required to wet the powder completely) of the powder increased significantly ($P < 0.05$) during storage. There was a significant difference ($P > 0.05$) among the wettability of the powders stored at different temperatures. Wettability of the powder sample at zero day was 3.67 ± 0.15 seconds at $55\text{ }^{\circ}\text{C}$ water temperature and increased to 10.33 ± 0.33 , 13.17 ± 0.44 and 18 ± 1.15 seconds for samples stored at 25, 37 and $45\text{ }^{\circ}\text{C}$, respectively at the end of 120 days. There was significant ($P < 0.05$) interaction between the storage period and temperature. Generally, wettability has a relation with surface properties of the powder particles. Changes in the water activity affects the wettability. Several authors have reported increase in wettability with storage period (Jha *et al.*, 1996; Patil, 2017).

Table 4.15 Effect of storage period and temperature on wettability (s) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	3.67 ± 0.15 ^{aAD}	3.67 ± 0.15 ^{aD}	3.67 ± 0.15 ^{aD}
2	20	4.54 ± 0.56 ^{aCD}	5.08 ± 0.27 ^{aD}	6.13 ± 0.70 ^{aC}
3	40	4.53 ± 0.69 ^{bBCD}	5.37 ± 0.74 ^{bD}	8.14 ± 0.64 ^{aC}
4	60	5.00 ± 0.58 ^{cCD}	7.33 ± 0.43 ^{bC}	10.50 ± 0.29 ^{aB}
5	80	5.86 ± 0.94 ^{bC}	7.48 ± 1.00 ^{bC}	11.00 ± 1.00 ^{aB}
6	100	8.20 ± 0.42 ^{bB}	10.67 ± 0.33 ^{bB}	12.33 ± 0.20 ^{aB}
7	120	10.33 ± 0.33 ^{cA}	13.17 ± 0.44 ^{bA}	18.00 ± 1.15 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-D) differ significantly (P < 0.05)

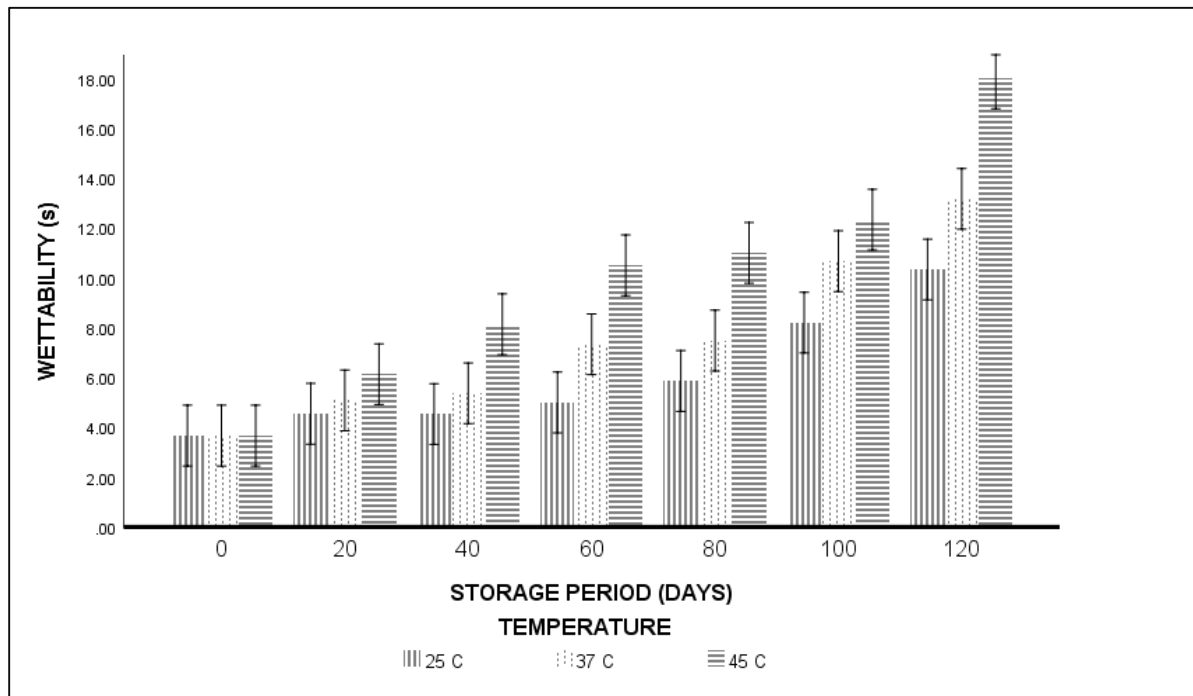


Fig. 4.12 Effect of storage period and temperature on wettability of spray dried camel milk powder

According to Gaiani *et al.* (2007), there is a strong correlation between changes in the lipid coverage on the surface and wetting properties during storage. The increase in the fat content increases the free fat content in the powder too (Kim *et al.*, 2002). The wetting time delayed while storing powder at higher temperature. When powder was stored for a longer period, wetting time increased significantly. The amount of fat and its dispersion affects the wettability of the powder negatively. As fat is hydrophobic, it inhibits wetting of milk powder.

4.3.11 Effect of Storage Period and Temperature on Dispersibility of the Spray Dried Camel Milk Powder

The values for dispersibility of the spray dried camel milk powder over the entire storage period are highlighted in the Table 4.16 and Fig. 4.13. The results indicate significant ($P < 0.05$) decrease in the dispersibility of the powder as storage proceeded. There was significant ($P < 0.05$) difference among the dispersibilities of powder stored at different temperatures. Dispersibility decreased from $67.83 \pm 0.44\%$ at zero day to 54.81 ± 1.28 , 50.95 ± 0.84 , $50.27 \pm 1.77\%$ at 25, 37 and 45°C , respectively at the end of 120 days. The interaction effect of storage period and temperature observed was non-significant ($P > 0.05$).

Table 4.16 Effect of storage period and temperature on dispersibility (%) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	$67.83 \pm 0.44^{\text{aA}}$	$67.83 \pm 0.44^{\text{aA}}$	$67.83 \pm 0.44^{\text{aA}}$
2	20	$66.23 \pm 0.50^{\text{aAB}}$	$64.97 \pm 1.02^{\text{aAB}}$	$64.00 \pm 1.26^{\text{aB}}$
3	40	$65.30 \pm 0.74^{\text{aBC}}$	$63.29 \pm 1.00^{\text{abB}}$	$60.77 \pm 1.16^{\text{bB}}$
4	60	$63.33 \pm 0.35^{\text{aC}}$	$56.87 \pm 0.90^{\text{bC}}$	$54.81 \pm 1.28^{\text{bC}}$
5	80	$58.60 \pm 0.81^{\text{aD}}$	$55.58 \pm 1.80^{\text{aC}}$	$54.48 \pm 0.87^{\text{aC}}$
6	100	$56.77 \pm 0.77^{\text{aE}}$	$54.81 \pm 1.28^{\text{aC}}$	$53.41 \pm 1.26^{\text{aCD}}$
7	120	$54.81 \pm 1.28^{\text{aE}}$	$50.95 \pm 0.84^{\text{aD}}$	$50.27 \pm 1.77^{\text{aD}}$

Mean \pm SE; n=3; values with different superscripts within a row (a-b) and column (A-E) differ significantly ($P < 0.05$).

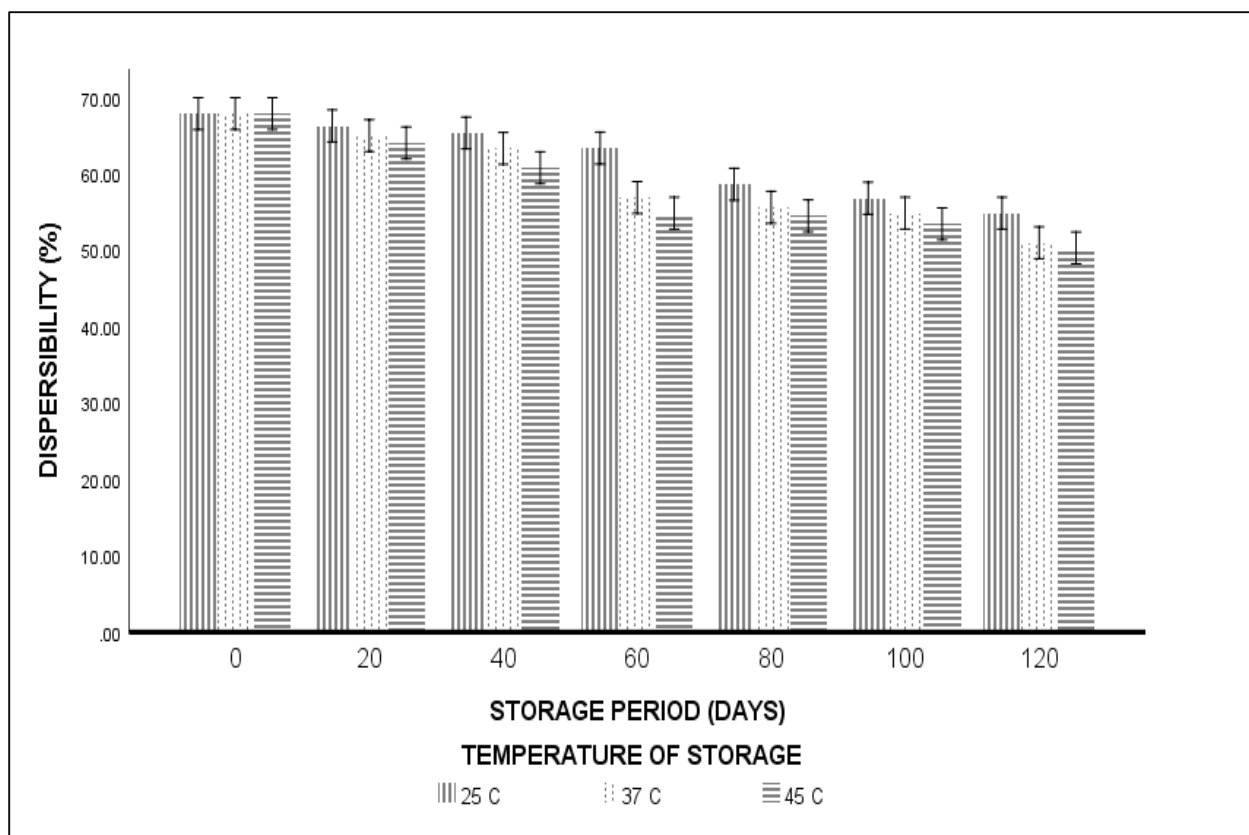


Fig. 4.13 Effect of storage period and temperature on dispersibility of the spray dried camel milk powder

Powder particles have the ability to be dispersed when they come in contact with water (Meena *et al.*, 2017). Increase in the surface oil content of the powder causes decreased entry of water inside the powder particles, resulting in the decreased dispersibility. Similar results have been reported by various studies (Khamrui, 2000; Kumar, 2011; Patil, 2017).

4.3.12 Effect of Storage Period and Temperature on Sinkability of the Spray Dried Camel Milk Powder

The values obtained for sinkability of the spray dried camel milk powder is presented in the Table 4.17 and Fig. 4.14 in the form of % transmittance. The sinkability of the powder during the storage period decreased non-significantly ($P > 0.05$) and there was no significant difference ($P > 0.05$) among the values obtained at different temperatures. The values observed for transmittance at the zero day was $88.19 \pm 22.83\%$, which decreased to 62.46 ± 9.57 , 57.95 ± 12.36 and $55.90 \pm 10.49\%$ at 25, 37 and 45 °C, respectively at the end of storage period of 120 days.

Table 4.17 Effect of storage period and temperature on sinkability (% transmittance) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	88.19 ± 22.83 ^{aA}	88.19 ± 22.83 ^{aA}	88.19 ± 22.83 ^{aA}
2	20	74.06 ± 9.83 ^{aA}	73.97 ± 11.51 ^{aA}	73.03 ± 9.85 ^{aA}
3	40	71.09 ± 9.61 ^{aA}	69.60 ± 11.00 ^{aA}	0.10 ± 9.35 ^{aA}
4	60	70.32 ± 9.48 ^{aA}	67.78 ± 11.02 ^{aA}	67.84 ± 9.41 ^{aA}
5	80	67.89 ± 9.24 ^{aA}	66.97 ± 11.05 ^{aA}	63.88 ± 9.69 ^{aA}
6	100	65.28 ± 9.46 ^{aA}	63.28 ± 10.67 ^{aA}	59.68 ± 9.81 ^{aA}
7	120	62.45 ± 9.57 ^{aA}	57.95 ± 12.36 ^{aA}	55.90 ± 10.49 ^{aA}

Mean ± SE; n=4; values with different superscripts within a row (a) and column (A) differ significantly (P < 0.05).

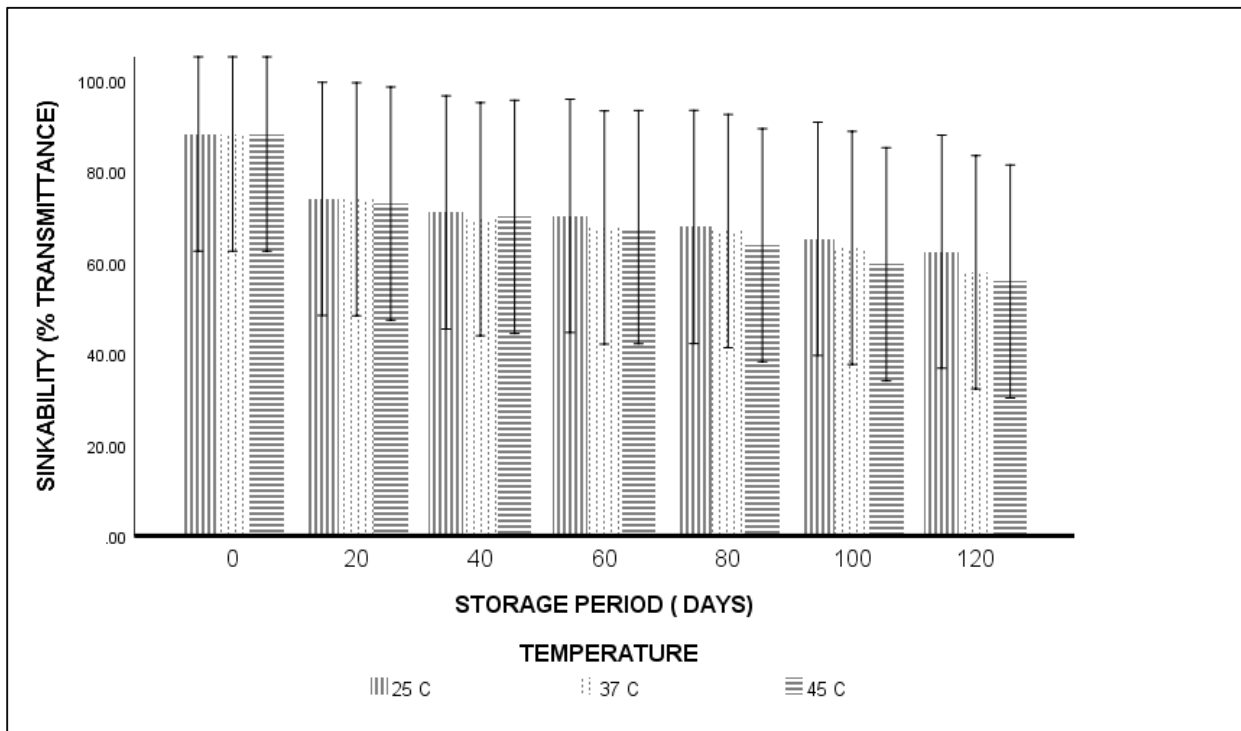


Fig. 4.14 Effect of storage period and temperature on sinkability of the spray dried camel milk powder

Non-significant ($P > 0.05$) interaction effect was noticed for the given values of % transmittance. Fang *et al.* (2008) defined sinkability as the falling of powder particles below the liquid surface. A higher particle density and lower porosity results in faster sinking of the powder (Caric & Milanovic, 2002). In the current study, particle density is getting reduced with storage period and hence sinkability.

4.3.13 Effect of Storage Period and Temperature on Solubility of the Spray Dried Camel Milk Powder

The values for solubility of spray dried camel milk powder are given in the Table 4.18 and Fig. 4.15. A significant ($P < 0.05$) decrease in the solubility of the powder sample was observed within the entire duration of storage. The solubility values at different temperature also differed significantly ($P < 0.05$). At zero-day, solubility was recorded as $98.58 \pm 0.13\%$, which reduced to 87.35 ± 0.36 , 89.56 ± 0.92 and $79.25 \pm 0.40\%$ at 25, 37 and 45 °C, respectively at the end of 120 days. Solubility is affected by storage time as mentioned by Bloor and Boag (1981).

Table 4.18 Effect of storage period and temperature on solubility (%) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	98.58 ± 0.13^{aA}	98.58 ± 0.13^{aA}	98.58 ± 0.13^{aA}
2	20	95.95 ± 0.72^{aB}	97.03 ± 0.73^{aAB}	96.75 ± 0.82^{aA}
3	40	95.56 ± 1.15^{aBC}	95.05 ± 0.47^{aBC}	91.35 ± 1.18^{aB}
4	60	92.81 ± 0.07^{aC}	95.34 ± 0.18^{aBC}	87.03 ± 1.50^{bC}
5	80	90.40 ± 0.43^{bD}	93.91 ± 0.29^{aC}	82.69 ± 0.71^{cD}
6	100	87.68 ± 0.81^{aE}	91.53 ± 1.06^{aD}	79.54 ± 1.29^{bDE}
7	120	87.35 ± 0.36^{aE}	89.56 ± 0.92^{aD}	79.25 ± 0.40^{bE}

Mean \pm SE; n=3; values with different superscripts within a row (a-c) and column (A-E) differ significantly ($P < 0.05$).

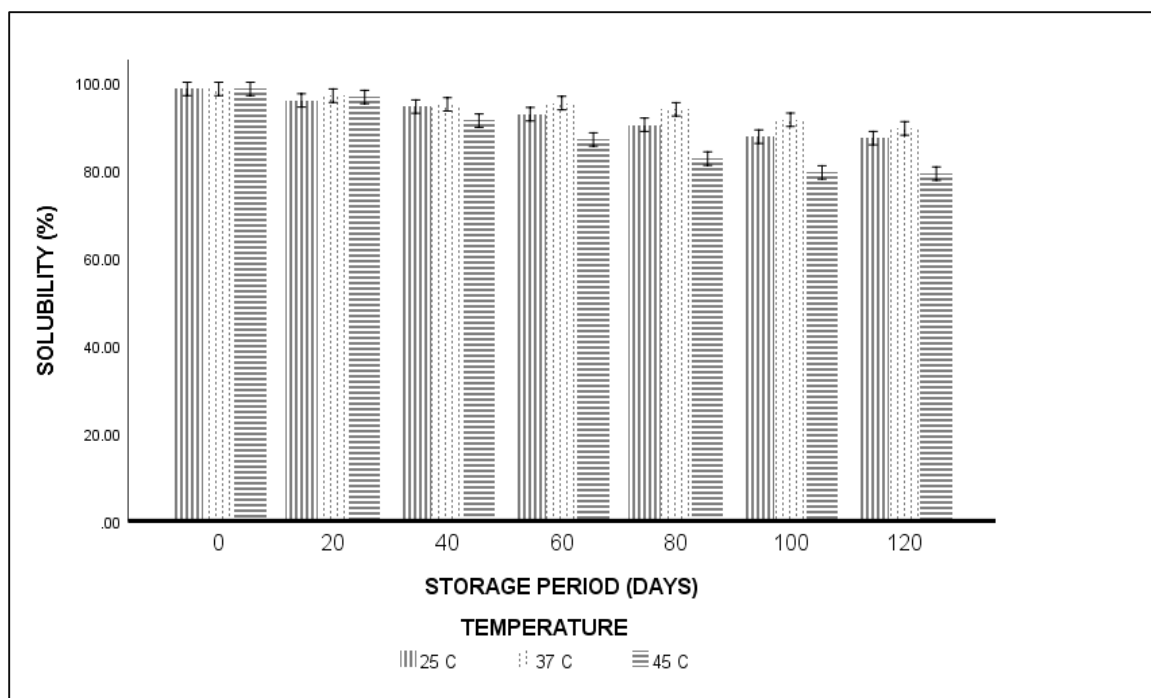


Fig. 4.15 Effect of storage period and temperature on solubility of the spray dried camel milk powder

Storage period and temperature had a significant ($P < 0.05$) interaction effect on the solubility values. Le *et al.* (2011) found that loss of solubility during storage at higher temperature could be attributed to change in the protein structure due to Maillard reaction and protein-protein interaction.

According to Stapelfeldt *et al.* (1997), polymerization of whey proteins occurring during storage reduces solubility. Solubility of powders with high fat content was observed as low (Erbay and Koca, 2015). Solubility of the spray dried camel milk powder was found to be 98.62% by Ho *et al.* (2019), which is in accordance to the present study. During storage, phase transformation of lactose damages the protein structure, which negatively affects the solubility of milk powder (Thomas *et al.*, 2004). It was reported that during the storage of spray dried cow milk powder at 37 °C, solubility reduced by approximately 15% due to migration of free fat on the surface (Kosasih *et al.*, 2016).

4.3.14 Effect of Storage Period and Temperature on the Foaming Properties of the Spray Dried Camel Milk Powder

Foaming properties of the milk powder is desirable for products in which air-water dispersion are required such as cakes, whipped toppings, etc. Foaming properties of milk powder is expressed in terms of foaming capacity and foaming stability. The values for foaming capacity and foaming stability are tabulated in the Tables 4.19 and 4.20, respectively, while the graphical representation is given in the Fig. 4.16 and 4.17, respectively. The results mentioned here indicate a significance ($P < 0.05$) decrease in both foaming capacity and stability with the storage period. Foaming capacity of the fresh powder sample was measured as $32.26 \pm 0.76\%$, which decreased to 12.45 ± 1.15 , 14.66 ± 1.30 and $18.28 \pm 0.58\%$ at 25, 37 and 45 °C, respectively at the end of 120 days. Foaming stability of the sample was calculated as 95.84 ± 0.06 which lowered down to 90.81 ± 0.10 , 92.03 ± 0.29 and $93.6 \pm 0.04\%$ at 25, 37 and 45 °C, respectively at the end of storage period of 120 days. Foaming capacity and stability differ significantly ($P < 0.05$) at different temperatures.

Table 4.19 Effect of storage period and temperature on foaming capacity (%) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	32.16 ± 0.76^{aA}	32.16 ± 0.76^{aA}	32.16 ± 0.76^{aA}
2	20	30.98 ± 0.98^{aA}	31.68 ± 0.96^{aA}	31.60 ± 1.39^{aAB}
3	40	27.42 ± 0.42^{bB}	27.54 ± 0.73^{bB}	30.56 ± 0.69^{aAB}
4	60	21.57 ± 1.3^{bC}	25.30 ± 0.44^{abBC}	28.41 ± 1.14^{aB}
5	80	16.88 ± 0.63^{bD}	21.50 ± 1.00^{aCD}	23.80 ± 0.19^{aC}
6	100	14.80 ± 1.20^{aDE}	18.19 ± 2.27^{aDE}	19.38 ± 0.63^{aD}
7	120	12.45 ± 1.15^{aE}	14.66 ± 1.30^{abE}	18.28 ± 0.58^{aD}

Mean \pm SE; n=3; values with different superscripts within a row (a-b) and column (A-C) differ significantly ($P < 0.05$).

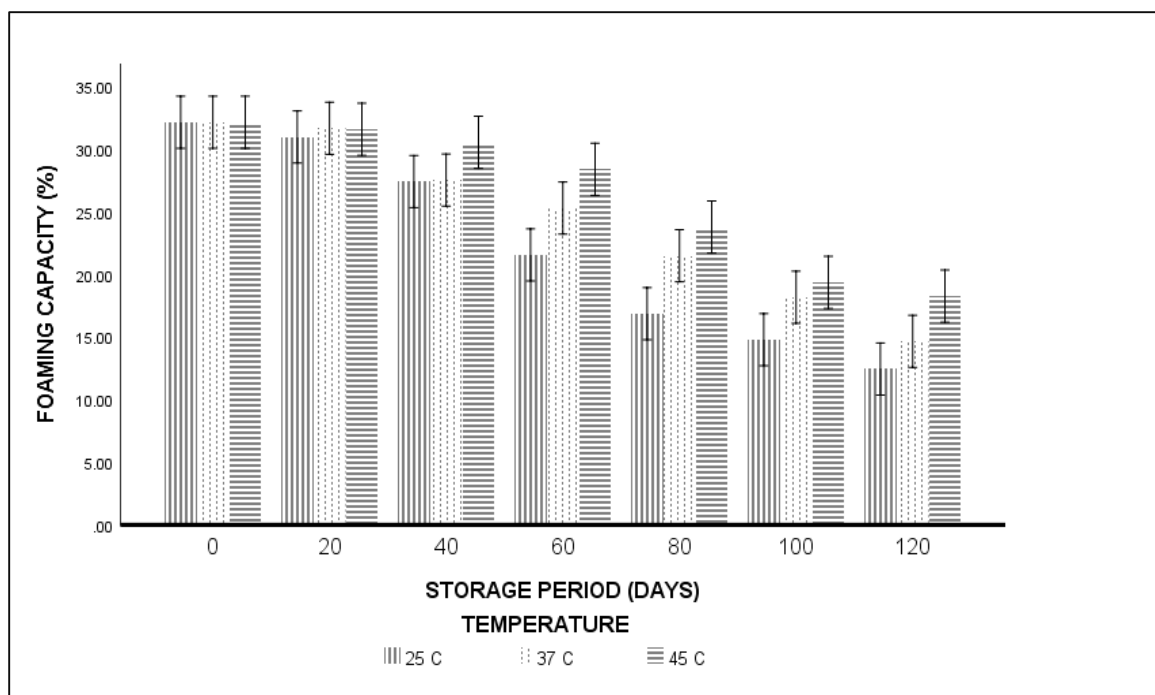


Fig. 4.16 Effect of storage period and temperature on foaming capacity of the spray dried camel milk powder

Table 4.20 Effect of storage period and temperature on foaming stability (%) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	95.84 ± 0.06 ^{aA}	95.84 ± 0.06 ^{aA}	95.84 ± 0.06 ^{aAA}
2	20	94.40 ± 0.12 ^{aAB}	94.84 ± 0.27 ^{aAB}	95.39 ± 0.41 ^{aAB}
3	40	93.62 ± 1.07 ^{bB}	94.23 ± 0.41 ^{aABC}	95.20 ± 0.44 ^{aABC}
4	60	92.94 ± 0.94 ^{aBC}	93.62 ± 1.13 ^{aBCD}	94.75 ± 0.01 ^{aABCD}
5	80	92.46 ± 0.27 ^{aBC}	93.06 ± 0.66 ^{aBCD}	94.36 ± 0.49 ^{aBCD}
6	100	91.08 ± 0.76 ^{aC}	92.55 ± 0.41 ^{aCD}	93.83 ± 0.71 ^{aCD}
7	120	90.81 ± 0.10 ^{cC}	92.03 ± 0.29 ^{bD}	93.60 ± 0.04 ^{aD}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-D) differ significantly (P < 0.05).

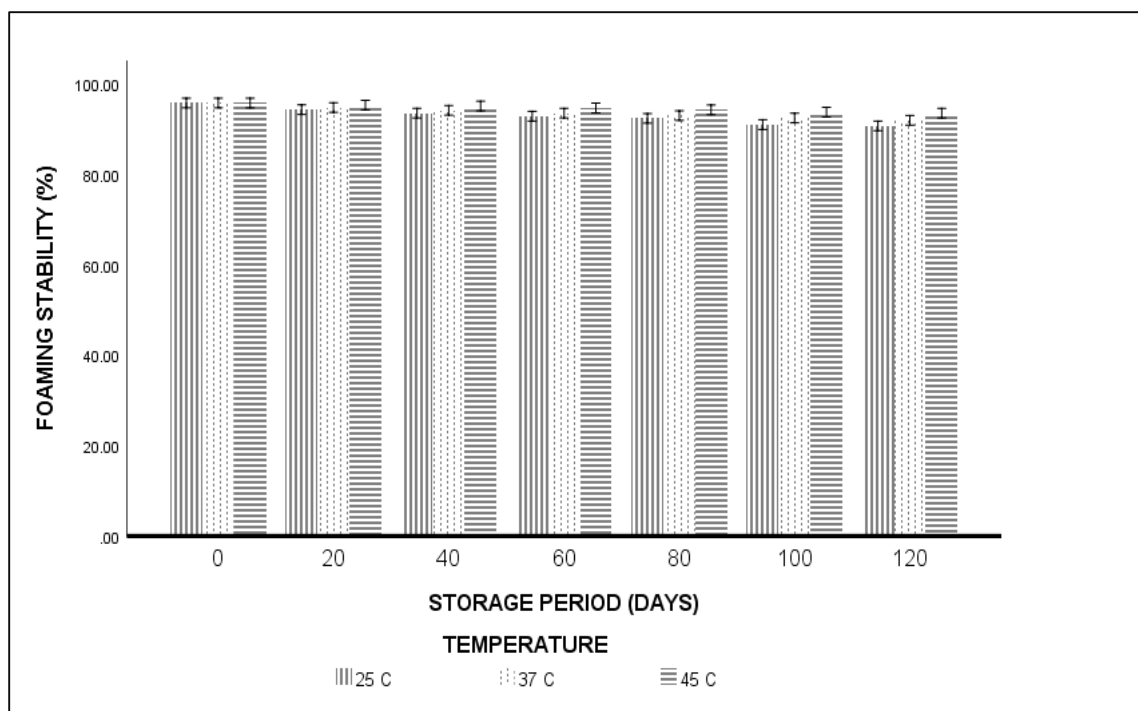


Fig. 4.17 Effect of storage period and temperature on foaming stability of spray dried camel milk powder

Non-significant ($P > 0.05$) interaction of storage period and temperature was observed for both foaming capacity as well as stability. It is concluded that the foaming properties of the powder sample reduced with the storage time. Foaming capacity and stability depends on the amphiphilic behaviour (polar/non-polar) of the (Du *et al.*, 2002). Maillard reaction degrades the foaming properties of milk powder. As per the study conducted by Norwood *et al.* (2016), foams made from powder stored at 60 °C were denser and more stable in comparison with the one stored at ≤ 40 °C. Foegeding *et al.* (2006) mentioned that the coexistence of aggregated and non-aggregated proteins is known to be an important parameter for foaming properties.

4.3.15 Effect of Storage Period and Temperature on Peroxide Value (meq peroxides/kg oil) of the Spray Dried Camel Milk Powder

Peroxide value (PV) of the spray dried camel milk powder as meq peroxides/kg oil is presented in the Table 4.21 and Fig. 4.18. Peroxide value of the sample powder increased significantly ($P < 0.05$) with the storage time. Sample stored at higher temperature had higher peroxide value.

Table 4.21 Effect of storage period and temperature on peroxide value (meq peroxides/kg oil) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	-	-	-
2	20	-	-	-
3	40	2.44 ± 0.19 ^{bC}	2.97 ± 0.21 ^{bB}	3.93 ± 0.20 ^{aA}
4	60	2.86 ± 0.18 ^{bCB}	3.54 ± 0.18 ^{abBA}	4.35 ± 0.18 ^{aA}
5	80	3.28 ± 0.21 ^{bBC}	3.72 ± 0.20 ^{abBA}	4.45 ± 0.19 ^{aA}
6	100	3.56 ± 0.20 ^{bBC}	3.96 ± 0.21 ^{abA}	4.48 ± 0.19 ^{aA}
7	120	3.77 ± 0.19 ^{aC}	4.13 ± 0.22 ^{aA}	4.65 ± 0.22 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a-b) and column (A-C) differ significantly (P < 0.05).

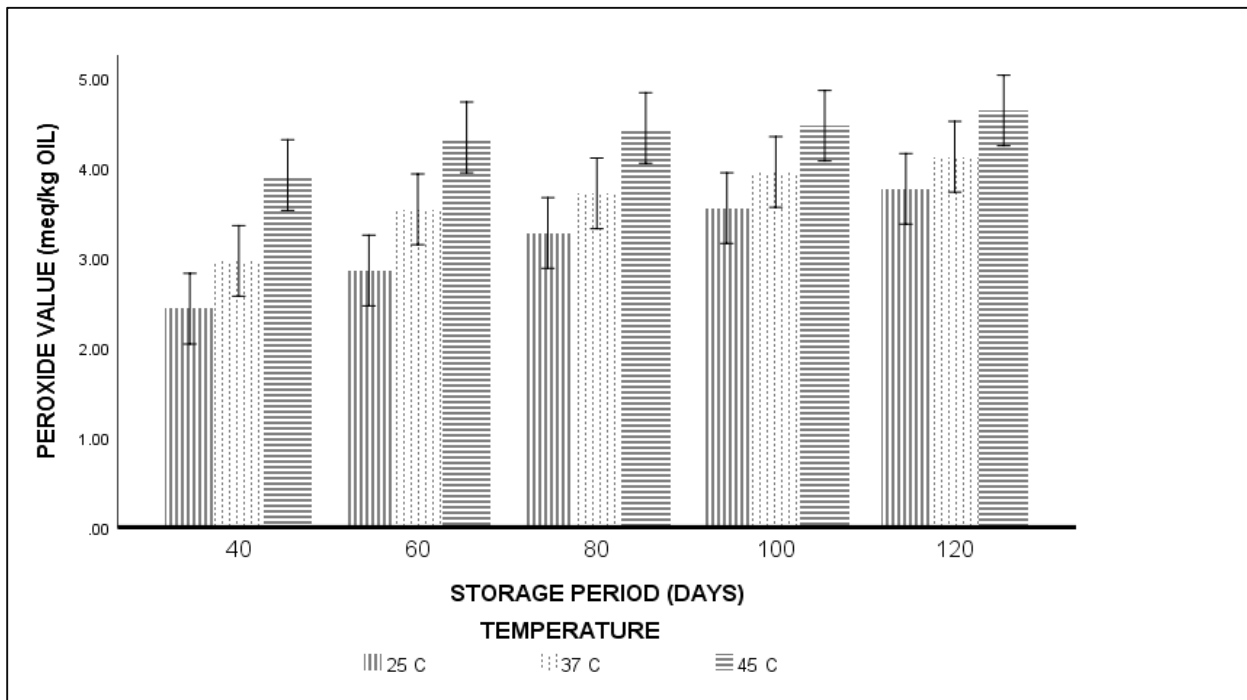


Fig. 4.18 Effect of storage period and temperature on peroxide value of the spray dried camel milk powder

Peroxide value of the fresh sample and the sample stored at 20 days of storage could not be determined in this study, due to some manual error. The value obtained for 40 days of storage at 25, 37 and 45 °C were 2.44 ± 0.19 , 2.97 ± 0.21 and 3.93 ± 0.20 meq/kg oil, respectively. At the end of storage, these values significantly ($P < 0.05$) increased to 3.77 ± 0.19 , 4.13 ± 0.22 and 4.65 ± 0.22 meq/kg oil at 25, 37 and 45 °C, respectively at the end of 120 days. There was a non-significant ($P < 0.05$) interaction between storage period and temperature for the given peroxide values.

Oxidative stability of polyunsaturated fatty acids (PUFA) is very important from the safety point of view. Peroxide value is used to assess the primary oxidation of oil or fat in a product and depends on the peroxides formed during primary oxidation. They have deteriorative effects on the quality of the product. As per the study conducted by Romeu-Nadal *et al.* (2007) on milk powder formulas, peroxide value increased with storage till 8 months and then declined and increased on elevated storage temperature within this period. Storage temperature is a key parameter for oxidation stability in powdered milk. Oxidation rate of fat present in the whole milk powder stored at low temperature is much slower, as compared to the one stored at higher temperature. High temperature accelerates the rate of oxidation in milk fat and decomposition of hydroperoxides in the milk powder (Stapelfeldt *et al.*, 1997).

4.3.16 Effect of Storage Period and Temperature on Total Plate Count of the Spray Dried Camel Milk Powder

Total plate count of the spray dried camel milk powder throughout the storage is expressed in log cfu/g and given in the Table 4.22 and Fig. 4.19. Total plate count of the samples increased significantly ($P < 0.05$) with storage. There was a significant difference ($P < 0.05$) between the samples stored at different temperatures. Also, there is a significant ($P < 0.05$) interaction between the storage period and temperature. The count on the zero-day was 2.18 ± 0.06 log cfu/g, which increased significantly ($P < 0.05$) to 3.19 ± 0.04 , 3.10 ± 0.03 and 3.07 ± 0.03 log cfu/g at 25, 37 and 45 °C, respectively at the end of storage period of 120 days. Faster increase in the count of powder stored at 25 °C can be attributed to higher moisture content and water activity of the sample. The total plate count of the spray dried camel milk powder after four months of storage was lower than the standards of FSSAI for milk powders. Generally, low or no growth of the microorganisms is seen in powders owing to their low water activity.

Table 4.22 Effect of storage period and temperature on total plate count (log cfu/ml) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	2.18 ± 0.06 ^{aE}	2.18 ± 0.06 ^{aE}	2.18 ± 0.06 ^{aE}
2	20	2.39 ± 0.06 ^{aD}	2.26 ± 0.04 ^{aE}	2.21 ± 0.03 ^{aE}
3	40	2.63 ± 0.07 ^{aC}	2.48 ± 0.04 ^{abD}	2.37 ± 0.03 ^{bD}
4	60	2.99 ± 0.01 ^{aB}	2.81 ± 0.03 ^{bC}	2.64 ± 0.02 ^{cC}
5	80	3.04 ± 0.03 ^{aAB}	2.94 ± 0.02 ^{abB}	2.87 ± 0.03 ^{bB}
6	100	3.10 ± 0.02 ^{aAB}	3.01 ± 0.02 ^{a^bAB}	2.95 ± 0.03 ^{bB}
7	120	3.19 ± 0.04 ^{aA}	3.10 ± 0.03 ^{aA}	3.07 ± 0.03 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a-c) and column (A-E) differ significantly (P < 0.05).

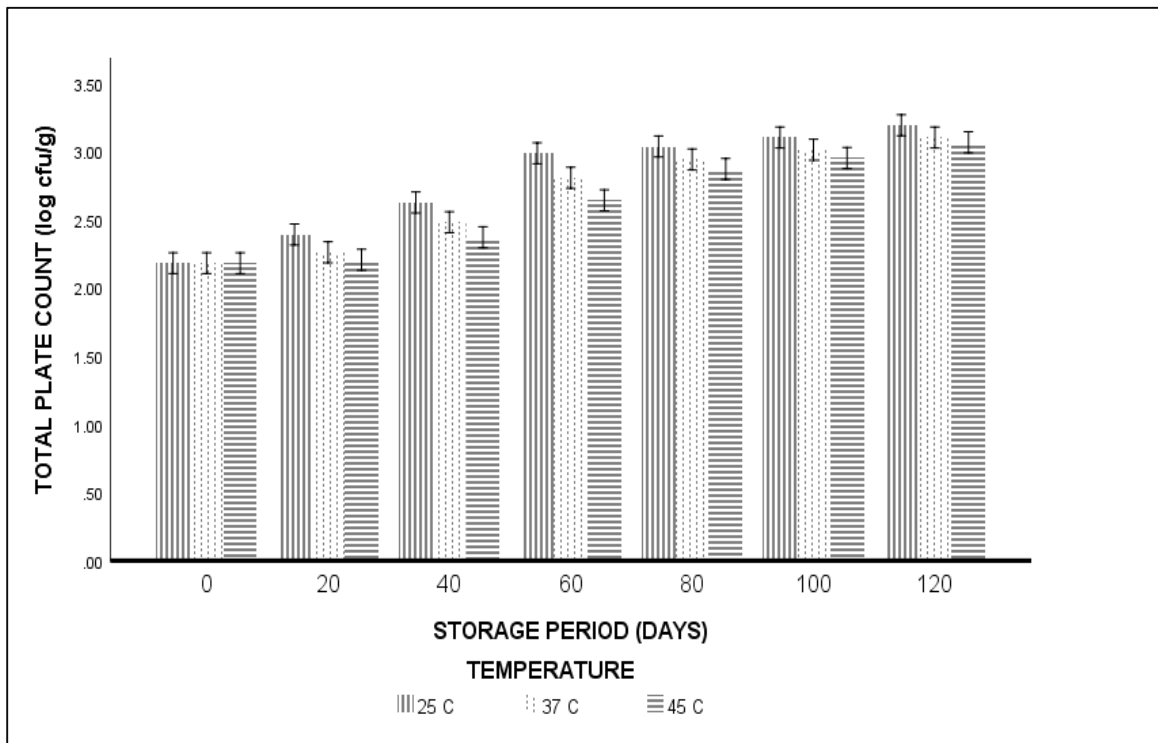


Fig. 4.19 Effect of storage period and temperature on total plate count of the spray dried camel milk powder

As growth was still observed, it could be due to entry of the microorganisms during various operations like production, handling and packaging of the powder sample. Fonceca *et al.* (2013) found increased growth of spoilage microorganisms in goat milk powder on storage. Kristanti and Herminiati (2021) also suggested that the total plate count pudding powder significantly increased on storage, probably due to change in water activity. Microbiological quality of the spray dried camel powder in the current study may be due to the adoption of good manufacturing practices.

4.3.17 Effect of Storage Period and Temperature on the Coliform Count of the Spray Dried Camel Milk Powder

Coliform count of the spray dried camel milk powder throughout the storage is expressed in log cfu/g of the powder and is mentioned in the Table 4.23 and Fig. 4.20. Coliform count of the sample increased significantly ($P < 0.05$) on storage. There was a significant ($P < 0.05$) difference between the coliform count obtained at different storage temperatures. The coliform count recorded on the zero day was 1.01 ± 0.01 log cfu/g, which increased significantly to 1.29 ± 0.01 , 1.25 ± 0.01 and 1.23 ± 0.01 log cfu/g at the end of 120 days at 25, 37 and 45 °C, respectively at the end of 120 days.

Table 4.23 Effect of storage period and temperature on the coliform count (log cfu/ml) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	1.01 ± 0.01^{aF}	1.01 ± 0.01^{aF}	1.01 ± 0.01^{aE}
2	20	1.07 ± 0.02^{aE}	1.06 ± 0.02^{aE}	1.03 ± 0.01^{aE}
3	40	1.13 ± 0.01^{aD}	1.12 ± 0.01^{aD}	1.06 ± 0.01^{bD}
4	60	1.19 ± 0.01^{aC}	1.15 ± 0.01^{abC}	1.12 ± 0.02^{bC}
5	80	1.21 ± 0.01^{aC}	1.18 ± 0.01^{abC}	1.16 ± 0.01^{bB}
6	100	1.25 ± 0.01^{aB}	1.21 ± 0.01^{aB}	1.19 ± 0.01^{bB}
7	120	1.29 ± 0.01^{aA}	1.25 ± 0.01^{bA}	1.23 ± 0.01^{bA}

Mean \pm SE; n=3; values with different superscripts within a row (a-b) and column (A-F) differ significantly ($P < 0.05$).

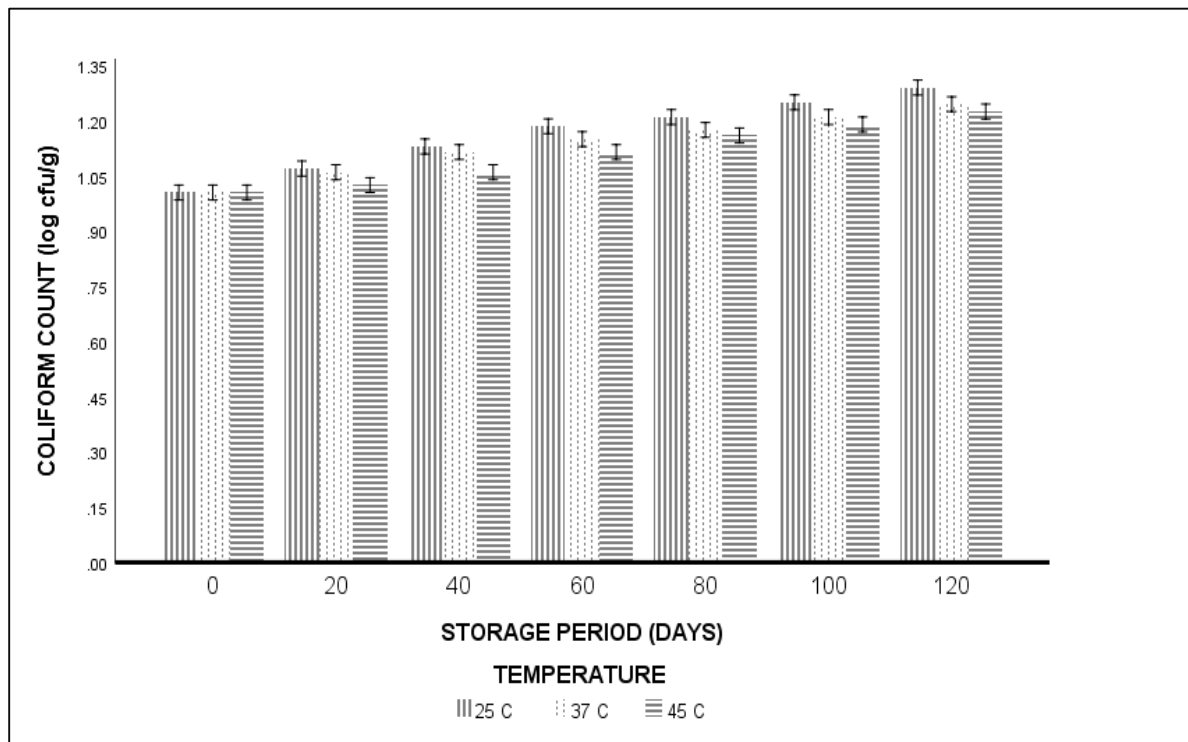


Fig. 4.20 Effect of storage period and temperature on coliform count of spray dried camel milk powder

A significant ($P < 0.05$) interaction could be seen between the storage period and temperature. Coliform is the indicator of hygiene. Al-Atrash (2019) confirmed that the coliform count of the infant formula increased on storage. The presence of coliform bacteria does not mandatorily suggest faecal contamination, but strictly as an indication of inadequate sanitary practices adopted during milking or further processing (El-Ziney and Al-Turki, 2007; Matofari *et al.*, 2013).

4.3.18 Effect of Storage Period and Temperature on the Yeast and Mold Count of the Spray Dried Camel Milk Powder

Yeast and mold count of the spray dried camel milk powder throughout the storage period is expressed in log cfu/g of powder and presented in the Table 4.24 and Fig. 4.21. Yeast and mold of the sample powder increased significantly ($P < 0.05$) within the duration of 120 days of storage.

Table 4.24 Effect of storage period and temperature on the yeast and mold count (log cfu/ml) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	1.04 ± 0.02 ^{aF}	1.04 ± 0.02 ^{aG}	1.04 ± 0.02 ^{aE}
2	20	1.10 ± 0.02 ^{aE}	1.08 ± 0.01 ^{abF}	1.05 ± 0.01 ^{bE}
3	40	1.17 ± 0.02 ^{aD}	1.13 ± 0.01 ^{aE}	1.12 ± 0.03 ^{aD}
4	60	1.23 ± 0.01 ^{aC}	1.19 ± 0.01 ^{abD}	1.17 ± 0.01 ^{bC}
5	80	1.26 ± 0.02 ^{aC}	1.24 ± 0.02 ^{aC}	1.22 ± 0.02 ^{aC}
6	100	1.34 ± 0.01 ^{aB}	1.31 ± 0.02 ^{aB}	1.30 ± 0.02 ^{aB}
7	120	1.39 ± 0.01 ^{aA}	1.39 ± 0.01 ^{aA}	1.37 ± 0.01 ^{aA}

Mean ± SE; n=3; values with different superscripts within a row (a-b) and column (A-G) differ significantly (P < 0.05)

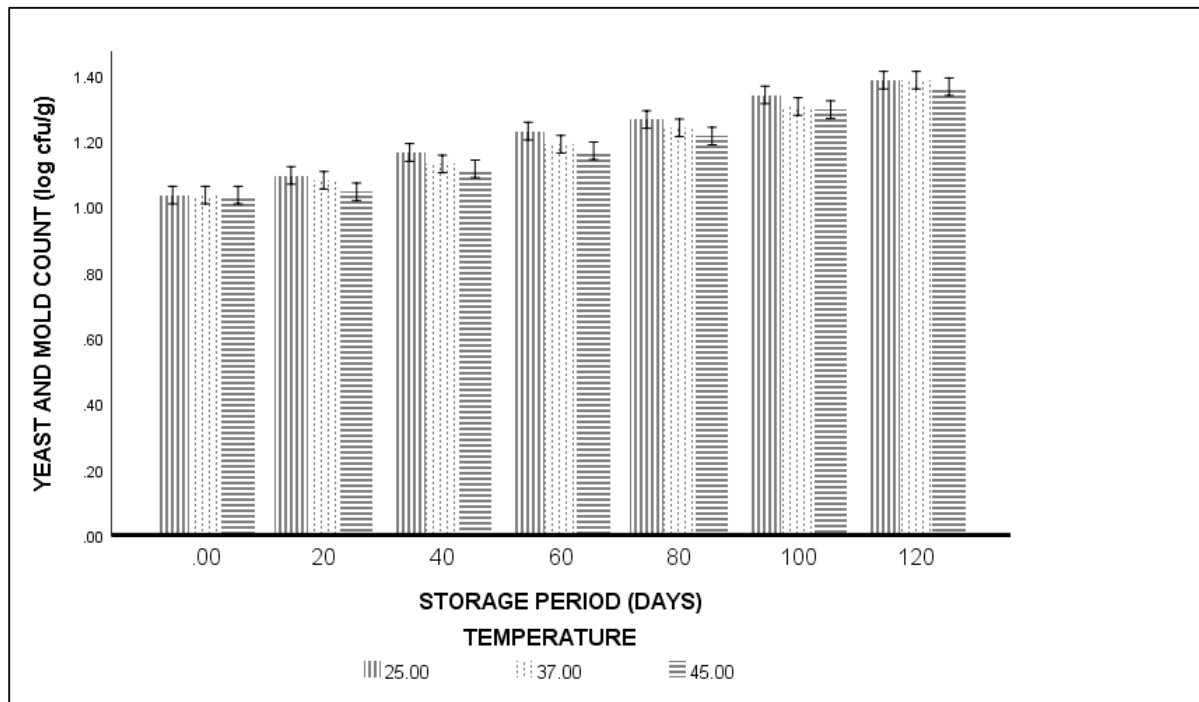


Fig. 4.21 Effect of storage period and temperature on yeast and mold count of spray dried camel milk powder

Also, there was a significant difference ($P < 0.05$) in the yeast and mold count of powder sample obtained at different storage temperatures. The interaction effect seen between the storage period and temperature was significant ($P < 0.05$). Maximum yeast and molds are observed at 25 °C compared to 37 and 45 °C can be related to the highest values of water activity measured at that temperature. Yeast and mold count for the fresh powder was calculated as 1.04 ± 0.02 log cfu/g, which increased significantly to 1.39 ± 0.01 , 1.39 ± 0.01 and 1.37 ± 0.01 at 25, 37 and 45 °C, respectively at the end of 120 days. Fonseca *et al.* (2013) reported the similar results suggesting increase in the microbial growth as the storage proceeded.

4.3.19 Effect of Storage Period and Temperature on the Thermophilic Spore Count of the Spray Dried Camel Milk Powder

Thermophilic spore count of the spray dried camel milk powder within the period of storage is expressed as log cfu/g of powder and is represented in the Table 4.25 and the Fig. 4.22. Spore count of the powder increased significantly ($P < 0.05$) with the storage time.

Table 4.25 Effect of storage period and temperature on the thermophilic spore count (log cfu/ml) of the spray dried camel milk powder

S. No.	Storage period (days)	Storage Temperatures		
		25 °C	37 °C	45 °C
1	0	1.13 ± 0.01^{aD}	1.13 ± 0.01^{aF}	1.13 ± 0.01^{aG}
2	20	1.18 ± 0.03^{aCD}	1.18 ± 0.01^{aE}	1.24 ± 0.01^{aF}
3	40	1.24 ± 0.01^{bB}	1.21 ± 0.01^{cE}	1.33 ± 0.01^{aE}
4	60	1.31 ± 0.02^{bA}	1.32 ± 0.02^{bD}	1.46 ± 0.01^{aD}
5	80	1.21 ± 0.02^{cBC}	1.39 ± 0.01^{bC}	1.52 ± 0.01^{aC}
6	100	1.15 ± 0.03^{cCD}	1.43 ± 0.01^{bB}	1.64 ± 0.01^{aB}
7	120	1.15 ± 0.01^{cCD}	1.47 ± 0.01^{bA}	1.91 ± 0.03^{aA}

Mean \pm SE; n=3; values with different superscripts within a row (a-c) and column (A-G) differ significantly ($P < 0.05$)

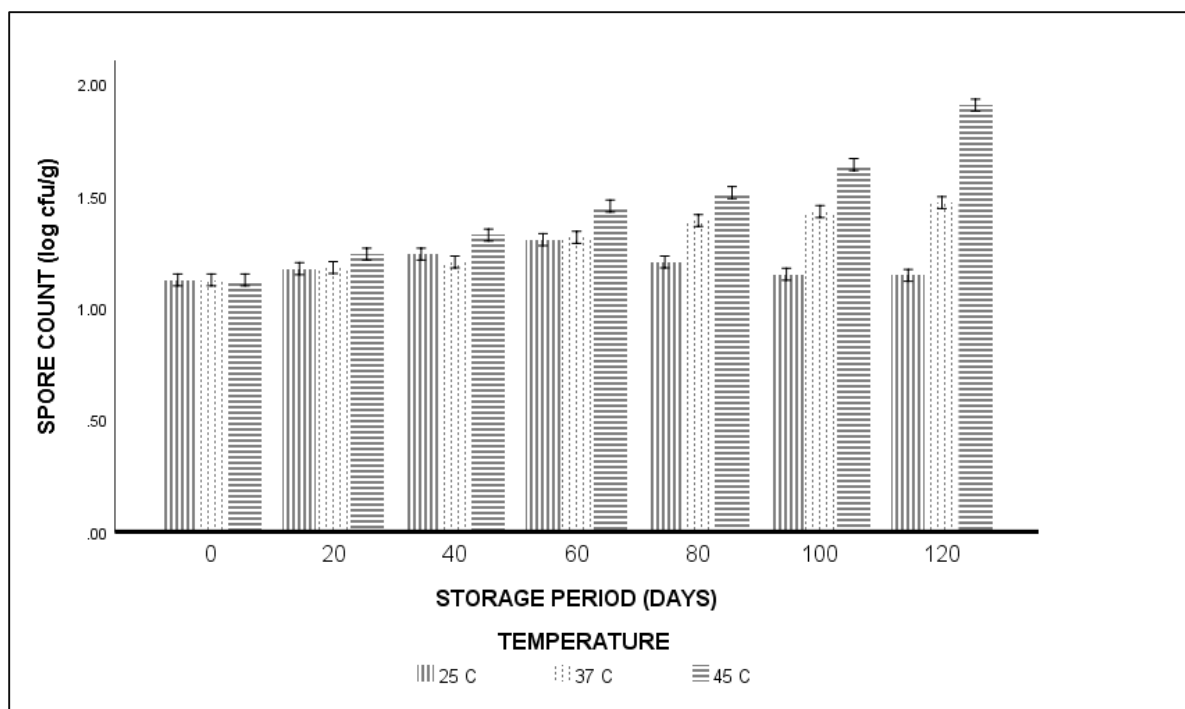


Fig. 4.22 Effect of storage period and temperature on the thermophilic spore count of spray dried camel milk powder

A significant difference ($P < 0.05$) was observed among the spore counts of the powders stored at different temperatures. For the fresh powder, spore count was calculated as 1.13 ± 0.01 log cfu/g of powder and increased significantly to 1.15 ± 0.01 , 1.47 ± 0.01 and 1.91 ± 0.03 log cfu/g at 25, 37 and 45 °C, respectively, at the end of storage period of 120 days.

Some decrease in the spore count was observed at 25 °C. Thermophilic spores thrive at elevated temperatures > 45 °C, which might be the reason for decrease of spore count at 25 °C. There was significant interaction effect ($P < 0.05$) between the storage period and temperature.

Chauhan and Patil (2013) reported insignificant decrease in the spore count in the powder stored at 30 and 5 °C. Muir *et al.* (1986) observed similar results and suggested insignificant decrease in spore count after storage of powder at 30 °C. Spore forming bacteria can enter dairy powder by various means via raw milk, processing sectors and even biofilms.

The current research revealed that the spray dried camel milk powder sample packaged in the metal laminates is safe for consumption and/or as an ingredient for incorporation in various food products for a period of four months under study (in terms of microbiological activity and fat

oxidation). The reconstititional and functional properties changed upon storage, causing slight decrease in the values. The different temperatures (25, 37 and 45 °C) used for the storage of powder sample had an influence over the quality. Major changes in the reconstititional properties took place due to absorption of moisture at low storage temperature and chemical changes due to melting of fat or state transition of amorphous lactose at higher storage temperature.

Further, storage study can be conducted by packing powder samples in different packaging materials to check their suitability. Moreover, powder sample can be utilized for the preparation of products to have a detailed idea of the further use and changes in the reconstititional and functional properties. Comparison between the products formulated by using camel milk and camel milk powder can be done and their physical as well as nutritional significance can be known. As not much information is known about the functional properties of the camel milk powder, future research efforts on them would make this a complete study.

5. SUMMARY AND CONCLUSION

5.1 PROLOGUE

For centuries, camel milk has been used by the nomadic people due to its medicinal properties. It is considered better than cow milk and similar to human and goat milks. It can be kept longer than cow milk at refrigeration temperatures, as it sours slowly. The absence of β -lactoglobulin further makes it non-allergic to humans. The milk produced by dehydrated camels is rich in water and salts like potassium, sodium, phosphorus and chloride. It is being used for the treatment of several diseases like diabetes, autism, diarrhea, and has anti-tumors properties. The demand for camel milk is rising owing to its therapeutic and functional properties. But the production of camel milk in limited regions imposed a need to find an alternative ways for its availability throughout the world. Literature available shows that there have been several attempts made to produce freeze dried powders, but its production was not cost-effective. A few researchers have attempted to spray dry the camel milk. They evaluated the effect of pre-processing treatments on camel milk and optimization of processing variables for spray drying. Therefore, present study has been conducted to determine the storage stability with the following objective and its activities:

To study the effect of storage on physiochemical, reconstititional and functional properties of camel milk powder.

- Activity 1. Determination of moisture sorption isotherm of prepared camel milk powder for predicting its shelf life
- Activity 2. Analysis of quality parameters of spray dried camel milk powder packed in single layered aluminum pouches and stored at different temperatures for determining storage stability

The results obtained have been summarized in this chapter.

5.2 PROXIMATE COMPOSITION

The moisture, fat, protein, ash and lactose contents of the spray dried camel milk powder were, respectively, $1.42 \pm 0.17\%$, $27.86 \pm 0.13\%$, $26.80 \pm 0.51\%$, $8.04 \pm 0.09\%$ and $35.84 \pm 0.39\%$.

5.3 MOISTURE SORPTION ISOTHERM

The moisture sorption isotherms obtained for the spray dried camel milk powder at all the three temperatures of storage i.e., 25, 37 and 45 °C were Type II isotherms. They indicated increase in the equilibrium moisture content with the increase in water activity for all the three temperatures. However, equilibrium moisture content at lower temperature (25 °C) was 23.5% on dry basis, which was lower than 18.55 and 14.67% at 37 and 45 °C, respectively.

Monolayer moisture content (M_o) is the minimum value of moisture at which storage stability is assured. The values for monolayer moisture content by BET model decreased from 3.17% at 25 °C to 2.60 and 1.63 at 37 and 45 °C, respectively. Gab model also followed the same trend, M_o decreasing from 3.21% at 25 °C to 2.66 and 1.77% at 37 and 45 °C, respectively. M_o calculated by the BET equation was found to be lower than the M_o obtained by the GAB model, for all the three temperatures. The results suggested that lower moisture content is required at higher temperature to increase the shelf life of the spray dried camel milk powder.

5.4 ASSESSMENT OF PHYSICOCHEMICAL, RECONSTITUTIONAL, FUNCTIONAL AND MICROBIAL CHANGES IN SPRAY-DRIED CAMEL MILK POWDER DURING STORAGE

Moisture content of the spray dried camel milk powder in the current study increased significantly ($P < 0.5$) with storage period at all temperatures. However, it decreased significantly ($P < 0.5$) as the temperature increased. Moisture content of the powder on the zero day was $1.42 \pm 0.17\%$, which increased significantly ($P < 0.05$) at the end of 120 days to 2.95 ± 0.21 , 2.67 ± 0.07 and $2.34 \pm 0.34\%$ at 25, 37 and 45 °C, respectively.

Water activity of the fresh powder sample was recorded as 0.13 ± 0.00 , which increased significantly ($P < 0.05$) to 0.27 ± 0.00 , 0.17 ± 0.00 and 0.15 ± 0.00 at 25, 37 and 45 °C, respectively, at the end of 120 days. At all the temperatures, lightness decreased significantly ($P < 0.05$) during the storage from 86.47 ± 0.05 to 85.64 ± 0.04 , 84.97 ± 0.05 and 83.76 ± 0.04 at 25 °C, 37 °C and 45 °C respectively. At higher temperature, Maillard reaction caused decrease in the lightness of the powder. Greenness of the powder decreased significantly ($P < 0.05$) as storage proceeded. The fresh spray dried camel milk powder had an a^* value of -1.9 ± 0.05 which decreased to -1.40 ± 0.00 , -1.15 ± 0.18 and -0.40 ± 0.02 at 25, 37 and 45 °C, respectively at the end of 120 days. There is a significant ($P < 0.05$) increase in the yellowness of the powder with the storage period from

10.85 ± 0.13 on the zero day to 16.29 ± 0.02, 18.21 ± 0.17 and 20.72 ± 0.03, at 25, 37 and 45 °C, respectively. The bulk density reduced significantly ($P < 0.05$) from 0.39 ± 0.01 for fresh camel milk powder to 0.35 ± 0.01, 0.34 ± 0.00 and 0.34 ± 0.01 g/cm³ at 25, 37 and 45 °C respectively at the end of 120 days. There is a significant ($P < 0.05$) decrease in the bulk density as we move to higher temperature. The decrease in the value of tapped density with the storage period is statistically significant ($P < 0.05$). The value for fresh camel milk powder was determined as 0.42 ± 0.01 g/cm³, which reduced to 0.40 ± 0.00 and 0.39 ± 0.01 g/cm³ at 25 and 37 °C respectively and remains nearly constant as 0.42 ± 0.00 at 45 °C at the end of storage period of 120 days. Flowability of the powder reduced more at higher storage temperature due to melting of fat and lower temperature by absorbing moisture. Highest flowability was recorded for the room temperature. Carr Index increased significantly ($P < 0.05$) from 5.62 ± 0.62 to 14.96 ± 0.96, 13.77 ± 0.73 and 16.91 ± 0.24 at 25, 37 and 45 °C, respectively at the end of 120 days. Similarly, Hausner ratio increased significantly ($p < 0.05$) from 1.06 ± 0.01 to 1.18 ± 0.01, 1.16 ± 0.01 and 1.21 ± 0.00 at 25, 37 and 45 °C, respectively at the end of 120 days. True density of the powder was calculated as 1.19 ± 0.07 g/cm³, which decreased to 0.91 ± 0.00, 0.90 ± 0.01 and 0.89 ± 0.00g/cm³ at 25, 37 and 45 °C, respectively at the end of the storage period of 120 days.

Wettability of the powder sample at zero day was 3.67 ± 0.15 seconds at 55 °C water temperature and increased to 10.33 ± 0.33, 13.17 ± 0.44 and 18 ± 0.15 seconds for samples stored at 25, 37 and 45 °C, respectively at the end of 120 days. Dispersibility decreased significantly ($P < 0.05$) from 67.83 ± 0.44% at zero day to 54.81 ± 1.28, 50.95 ± 0.84, 50.27 ± 1.77% at 25, 37 and 45 °C, respectively at the end of 120 days. The values observed for transmittance at the zero day was 88.19 ± 22.83%, which decreased non-significantly ($P < 0.05$) to 62.46 ± 9.57, 57.95 ± 12.36 and 55.90 ± 10.49% at 25, 37 and 45 °C, respectively at the end of storage period of 120 days. This indicates that sinkability increased non-significantly ($P < 0.05$) with the storage period. More increase in sinkability was observed at higher temperature. A significant ($P < 0.05$) decrease in the solubility of the powder sample was observed from 98.58 ± 0.13% at zero day to 87.35 ± 0.36, 89.56 ± 0.92 and 79.76 ± 0.40% at 25, 37 and 45 °C, respectively at the end of 120 days. Both foaming capacity and stability decreased significantly ($P < 0.05$) during the storage period. Foaming capacity of the fresh powder sample was measured as 32.26 ± 0.76%, which significantly ($P < 0.05$) decreased to 12.45 ± 1.15, 14.66 ± 1.30 and 18.28 ± 0.58% at 25, 37 and 45 °C,

respectively at the end of 120 days. Foaming stability of the sample was calculated as 95.84 ± 0.06 initially, which lowered down to 90.81 ± 0.10 , 92.03 ± 0.29 and $93.6 \pm 0.04\%$ at 25, 37 and 45 °C, respectively, at the end of storage period of 120 days. Peroxide value of the fresh sample and the sample stored at 20 days of storage could not be determined in this study, due to some manual error. The value obtained for 40 days of storage at 25, 37 and 45 °C were 2.44 ± 0.19 , 2.97 ± 0.20 and 3.93 ± 0.22 meq/kg oil, respectively. These values increased significantly ($P < 0.05$) to 3.77 ± 0.19 , 4.13 ± 0.22 and 4.65 ± 0.22 meq/kg oil at 25, 37 and 45 °C, respectively at the end of 120 days. The peroxides formed have deteriorative effects on the quality of the product. High storage temperature had increased the rate of oxidation in milk fat and decomposition of hydroperoxides in the milk powder.

The total plate count on the zero-day was 2.22 ± 0.10 log cfu/g, which increased significantly ($P < 0.05$) to 4.06 ± 0.03 , 3.72 ± 0.06 and 3.57 ± 0.13 log cfu/g at 25, 37 and 45 °C, respectively, at the end of storage period of 120 days. The coliform count recorded on the zero day was 1.005 ± 0.01 log cfu/g, which increased significantly to 1.95 ± 0.09 , 1.59 ± 0.02 and 1.37 ± 0.02 log cfu/g at the end of 120 days at 25, 37 and 45 °C, respectively, at the end of 120 days, giving an indication of unhygienic practices adopted during milking or further processing. Yeast and mold of the sample powder increased significantly ($P < 0.05$) from 1.04 ± 0.02 log cfu/g, which increased significantly to 1.51 ± 0.01 , 1.49 ± 0.01 and 1.47 ± 0.01 at 25, 37 and 45 °C, respectively, within the duration of 120 days of storage. For the fresh powder, spore count was calculated as 1.13 ± 0.01 log cfu/g of powder and increased significantly to 1.15 ± 0.03 , 1.47 ± 0.01 and 1.91 ± 0.01 log cfu/g at 25, 37 and 45 °C, respectively, at the end of storage period of 120 days. Thermophilic spores generally grow at elevated temperatures > 45 °C, which might be the reason for decrease of spore count at 25 °C.

5.5 CONCLUSION

The current study revealed that at lower temperature, powder has greater affinity to absorb moisture, which leads to slightly higher microbial activity. At higher temperature, powder became darker and more yellowish, less greenish. The bulk density, flowability, wettability, solubility and dispersibility are affected negatively by higher storage temperature. Foaming capacity and the peroxide value increased on increasing storage temperature. Spore count increased at higher temperature, while total plate count reduced. Overall, lower storage temperature is recommended

for the maximum retention of reconstititional properties with the use of proper packaging material with lower water vapour transmission rate. At all the storage temperatures employed in this study, the spray dried camel milk powder was found to be perfectly safe for consumption till the 4 months of storage period.

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