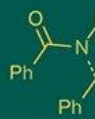


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## Study on chemical composition, chemical characteristics and heat load indicators of goat and cow milk powder

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### Abstract

The consumption scales of goat milk and its products are extensively expanding due to their nutritional and therapeutic properties. This study aimed to analyse goat milk powder for chemical composition, chemical characteristics and heat load indicators. The higher moisture content was found in goat milk powders than cow milk powder. The average fat content varied non-significantly ( $p > 0.05$ ) in all powder samples. The protein and ash content including chloride content was observed to be significantly ( $p < 0.05$ ) higher in goat milk powders than cow milk powder. The lactose content were found higher in COM. A significant ( $p < 0.05$ ) difference was observed in the Vitamin C content. Significantly ( $p < 0.05$ ) higher peroxide value, HMF, lactulose and WPNI were observed in cow milk powder than goat milk powder. Titratable acidity and antioxidant capacity of cow milk powder were found lower than the goat milk powder. The non-significant difference was observed in FFAs content of goat and cow milk powder.

**Keywords:** WPNI, HMF, vitamin C, goat milk powder, Cow milk powder, peroxide value

### Introduction

Goat is the most versatile animal that can survive in tropical, arid, humid, cold, desert and mountain conditions. The third most produced milk in the world is goat milk. Goat milk is considered to be superior in terms of numerous health benefits, and lower risk of allergy, when compared to the milk of other species. Goat milk has comparably high amounts of mineral contents, short- and medium-chains fatty acids (C4 to C12) than cow milk. Goat milk has substantially higher levels of glycerol ether, which might prove crucial for a newborn's nutrition. (Yangilar, 2013; Paez *et al.* 2006) [39, 26]. The world goat milk production is 19 million tonnes. India produces 5.6 million tonnes of goat milk (FAO, 2018) [11]. Asia is the continent constantly the largest producer of goat milk with a contribution of 58.35%, followed by Africa with a contribution 24.14%, Europe with a contribution 14.21% and the Americas with a contribution 3.31% (RACP, 2019) [29]. The total milk production in India was 210 MT with an annual growth of 5.81% during 2020-21 (RACP, 2019) [29].

Spray drying is a technology of transformation of liquid food or products into powder form and used more widely than any other drying method. Manufacturing of goat milk powder to extend shelf life also decrease the goaty flavour and promotes consumer acceptability. The principle of spray drying involves moisture evaporation from an atomized feed by mixing the spraying process and drying medium which is typically air. The temperature applied during the spray drying process might affect the powder's nutritional content and reconstitution properties (Schuck, 2011; Seth *et al.* 2017) [32, 33]. A hydroperoxide value is the main byproduct of lipid oxidation; they tend to decline as a result of the creation of secondary oxidation (Fonseca *et al.* 2013) [13]. TBA is the method used for the determination of secondary oxidation of fat containing dairy products during lipid oxidation, malonaldehyde (MA) is formed as a result of the degradation of polyunsaturated fatty acids.

The Maillard reaction occurs when reducing sugars and proteins in food interact biochemically. It starts with lactose condensation on the same amino acid residues in milk products and involves a variety of chemical processes.

Hydroxymethyl furfural is an intermediate product of the Maillard reaction, and it indicates the degree of the Maillard reaction during the shelf-life of milk powder. Lactulose is the isomerized derivative of lactose where the glucose moiety converted to fructose. The alkaline isomerization is facilitated by the free amino group of casein, transforms lactose into lactulose in heated milk and dry milk products. Time, temperature, and the environment's pH all have a role in the amount of lactulose formed when milk is processed. Whey proteins in milk are sensitive to heat and can be easily denatured at temperatures above 65 °C. The undenatured whey proteins are calculated as whey protein nitrogen index. The degree of these changes influences the functional properties, like heat stability, emulsifying, solubility, foaming and water binding abilities, sensory properties, etc., of the resultant powder. As a result, a milk powder's heat class is a proximate indicator of its functional characteristics (Thomas *et al.* 2004; ADMI). Despite extensive studies on milk powders, comparative data on commercially available goat vs cow milk powders using multiple heat load indicators under identical analytical frameworks remain limited.

## Materials and Methods

### Materials

The fresh spray dried goat milk powders and a spray dried cow milk powder (A2 type) used for this study were purchased from the market in India. The most commonly available two different brands of goat milk powders (GMP1 and GMP2) were selected for the study. A cow milk powder (COM) was also purchased from the market. The samples of goat and cow milk powders were analyzed for chemical composition, chemical characteristics and heat load indicators.

### Methods

#### Determination of chemical composition

In the present study, the analysis of chemical compositional and characteristics parameters moisture, fat Ash was carried out using standard methods *i.e.*, IDF/ISO/AOAC/FSSAI methods. The methods prescribed in GEA /FSSAI are generally adopted from standard/reference method with some modifications. The moisture content of goat and cow milk powders was determined using method described by ISO 5537/IDF 026:2004 and GEA Niro (2006). The total fat was determined by Gerber method IS 1224 (Part II):1977 and (GEA Niro, 2005). The total protein of milk powder sample was determined by *Kjeldahl* method (AOAC, 2000). Ash content of milk powders was determined as described by (IS 1165: 2002; GEA Niro 2006). Lactose content in camel milk powder and cow milk powder was estimated by difference. The chloride content of reconstituted milk was measured using Mohr's method (Hammer and Bailey, 1917). Vitamin C content of goat and cow milk powders was determined by the 2, 6 dichlorophenol indophenol method given by BIS (1981).

#### Determination of chemical characteristics

The titratable acidity was determined by method described in GEA Niro analytical method A 19 a (GEA Niro, 2006). The peroxide value of powder was determined by method described in AOAC (2006) <sup>[1]</sup>. The peroxide value of 5 g sample was measured by titration against a 0.002 N sodium thiosulfate solution using starch as an indicator after fat

extraction by chloroform for 6-12 h. The peroxide value was calculated by equation (1) and the obtained value was expressed as peroxide value in mEq/kg of fat.

$$\text{Peroxide Value} = \frac{(A-B) \times N \times 1000}{M} \quad (1)$$

A=volume of sodium thiosulphate solution required for the sample, B=volume of sodium thiosulphate solution required for the blank, N=Normality of sodium thiosulphate solution, M=mass in g of the sample taken

Free fatty acids (FFAs) were determined by the volumetric method given by Deeth *et al.* (1975) <sup>[9]</sup>. In this method the extraction mixture used that contained Iso-propanol: petroleum ether: 4 N sulfuric acid in a ratio of 40:10:1. The upper layer (5-8 ml) was titrated against 0.02 N methanolic KOH solution using 1% methanolic phenolphthalein indicator. Free fatty acids content was measured using equation (2).

$$\text{FFA (\% Oleic acid)} = \frac{(T \times N) \times 10^3}{P \times W} \quad (2)$$

T=ml of 0.02 N methanolic KOH, N=Normality of methanolic KOH solution, P = Proportion of upper layer of aliquot, W=Weight of sample taken in g

The TBA value was determined according to the method described by (Sun, 2013) <sup>[37]</sup>. The 35.2 ml of 12% (w/v) reconstituted milk was precipitated using 2 ml TCA solution of 40% (w/v) and 4 ml of ethanol solution of 95%. The milk fat and proteins were removed by filtration through Whatman no. 42 filter paper. 1 ml of TBA solution of 0.1 mol/L was added to the clarified filtrate, and incubated in a water bath at 60 °C for 60 min. The absorbance was measured at 538 nm.

The antioxidant capacity was determined using spectrophotometer at 517 nm against methanol as a blank. DPPH (2,2-diphenyl-1-picrylhydrazyl) is a stable free radical that used to measure the radical scavenging activity of antioxidants. Radical-scavenging activity was expressed as the inhibition percentage (Brand-Williams *et al.* 1995) <sup>[4]</sup>.

#### Determination of heat load indicators

The colourimetric method described by Keeney and Basette (1959) was used to determine free HMF and total HMF of powder. Absorbance of the solution was measured at 443 nm against the blank (distilled water) using 1.0 ml of 0.05 M TBA in a spectrophotometer. For measuring total HMF tubes were kept in boiling water bath for 1 h. This step was being excluded when measuring the free HMF content. The tubes were placed in water bath maintained at 40°C for 30 min after addition of 1 ml TBA. The free and total HMF was calculated by using the equation 3 and 4 respectively.

$$\text{Free HMF (micromoles/liter)} = (\text{Absorbance} - 0.015) \times 81 \quad (3)$$

$$\text{Total HMF (micromoles/liter)} = (\text{Absorbance} - 0.055) \times 87.5 \quad (4)$$

Lactulose content of goat and cow milk powders was determined using spectrophotometric method described by Amine *et al.* (2000). The (10%) reconstituted milk was precipitated using the carrez 1 and carrez 2 and filtered it through Whatman no. 42 filter paper. 0.5 ml selivanoff's

reagent was added in filtrate and placed in a water bath at  $90 \pm 0.1$  °C for 5 minutes. The absorbance was measured at 482 nm against blank.

The whey protein nitrogen index (WPNI) of goat and cow milk powders was determined using GEA Niro analytical method A 21 a method (GEA Niro, 2009) [15]. The spectrophotometer was adjusted to 100% transmittance using the blind sample, with the wavelength set at 420 nm. Then, the transmittance of the sample was measured within the 5 to 10 min after adding 10% HCl solution. Based on the transmittance of the sample, undenatured whey protein nitrogen was determined from the standard curve using the equation (5).

$$y = -0.148x + 13.306 \quad (5)$$

### Statistical analysis

The statistical analysis was done by using the simple and two-factorial completely randomized design (CRD), (Steel and Torrie, 1980) [34]. Data are expressed as the mean  $\pm$  standard deviation

## Results and Discussions

### Chemical composition of goat and cow milk powder

Water plays a significant role in the manufacturing of different milk powders, and it affects the product's chemistry, microbiological safety, nutritional value, appearance, as well as shelf life. The significant ( $p < 0.05$ ) difference in moisture content of all the powder samples was observed. The moisture content of GMP1 was found significantly ( $p < 0.05$ ) highest compared to GMP2 and COM. The average moisture content was found to be 2.81, 2.14 and 1.84% in GMP1, GMP2 and COM respectively. The moisture content of GMP1, GMP2 and COM was found between 2.72 to 2.87, 2.07 to 2.29 and 1.73 to 2.04% respectively. The variation in the moisture content among different powders might be due to the factors involving properties of the feed such as concentration, temperature, viscosity (Schuck, 2011; Seth *et al.* 2017) [32, 33]. The conditions of the drying like inlet and outlet temperature of the air, absolute humidity. The moisture content of goat milk and cow milk powder is affected by hot air temperature, design of the drying chamber, contact time of hot air with the milk particles, packaging material, storage conditions, etc (Zainil *et al.* 2019) [41]. Various workers reported on moisture content of goat milk powder from 2.0 to 5.25% (Fonseca *et al.* 2011) [12]. Moisture content from 1.83 to 4.78 was observed by workers (Sulieman *et al.* 2014; Pugliese *et al.* 2017; Magan *et al.* 2019) [28, 36, 24]. Food safety standard and authority of India (FSSR, 2011) have prescribed moisture content of maximum 5% standards for various milk powders such as whole milk powder, skimmed milk powder as well as partly skimmed milk powder.

Milk fat is an important source of desirable flavour and undesirable off-flavour in milk powders. Fat content also influences the functional properties as well as the reconstitution behaviour of the powder. The non-significant ( $p > 0.05$ ) variation in fat content of all the powder samples was observed. Overall, the highest fat content was found in cow milk powder compared to goat milk powder. Fat content was observed to be 28.18, 28.29 and 30.32% respectively in GMP1, GMP2 and COM as shown in Table 1. Fat content in GMP1 varied from 25.00 to 30.11% whereas 25.10 to 30.11% in GMP2. The fat content of

sample COM was varied from 29.00 to 31.50%. The fat content of goat and cow milk powders is affected by the milk of different species as well as milk of different breeds, temperature (Seth *et al.* 2017) [33]. Fat content of goat milk powder was reported 26.56 to 33.28 by various workers (Fonseca *et al.* 2011) [12]. The fat content in cow milk powder was observed 25.5 to 31.57% by different workers (Sulieman *et al.* 2014; Pugliese *et al.* 2017; Magan *et al.* 2019) [28, 36, 24]. The food safety standard and authority of India (FSSR, 2011) has prescribed standards for whole milk powder that it should have a fat content minimum of 26 and a maximum of 42%.

Protein is a valuable component of dried milks, which holds significant importance from a nutritional and economic point of view. A significant ( $p < 0.05$ ) difference in protein content of goat and cow milk powder was observed. The protein content of GMP2 was observed significantly ( $p < 0.05$ ) higher than GMP1 and COM. Sample COM showed significantly ( $p < 0.05$ ) lower protein content than the other two samples. In the present study the protein content was found in GMP1, GMP2 and COM as 27.00, 29.79 and 24.77% respectively. The range of protein content observed was 25.33 to 28.54 in GMP1, 28.73 to 30.48 in GMP2%. The range of protein content in COM was from 24.62 to 25.28%. The variation in the protein contents among the different samples might be due to various chemical reactions in which protein involves, interactions between proteins and other components during processing and other manufacturing parameters (Schuck, 2011) [32]. The protein content of goat milk and cow milk powder is affected by the milk of different species, milk of different breeds, hot air temperature, design of drying chamber, contact time of hot air with the milk particles, storage conditions, etc. Many workers have worked on the protein content of goat milk powder as well as cow milk powder. Several authors have reported on protein content of goat milk powder from 24.84 to 27.81% (Fonseca *et al.* 2011) [12]. (Pugliese *et al.* 2017; Magan *et al.* 2019) [28, 24] reported the protein content 24.7 to 31.7% in whole milk powder. Protein content in cow milk powder was found to be 22.44 to 25.66 by Elsara (2009) and Sulieman *et al.* (2014) [36].

Ash content was found non-significant ( $p > 0.05$ ) between the goat milk powder. Significantly ( $p < 0.05$ ) lowest ash content was observed in cow milk powder compared to both goat milk powder. Ash content in cow milk powder was found to be 5.73 whereas 6.43 to 6.45% in goat milk powders. Ash content of GMP1 varied from 6.20 to 6.67% whereas 6.13 to 6.72% were found in GMP2 samples. Ash content in COM varied from 5.51 to 6.01%. The variation in the ash contents between goat milk powder and cow milk powder might be due to variations in the mineral content of raw milk, conditions of the drying and other processing parameters (Schuck, 2011; Zainil *et al.* 2019) [32, 41]. During the analysis, chloride content was found higher in goat milk powder compared to cow milk powder which also is the reason for the variation in ash content. Ash content of goat milk and cow milk powder is influenced by species to species and breed to breed, design of drying chamber and contact time of hot air with the milk particles etc. Ash content in cow milk powder was reported by Elsara (2009) and Sulieman *et al.* (2014) [36] from 5.71 to 5.83. Fonseca *et al.* (2011) [12] reported ash content from 6.40 to 6.80% in goat milk powder. Ash content in whole milk powder reported by various workers from 5.1 to 7.0% (Pugliese *et*

*al.* 2017; Magan *et al.* 2019) [28, 24]. The food safety standard and authority of India (FSSR, 2011) have prescribed standards for milk powders such as whole milk powder in which a maximum of 9.3% ash content is allowed.

Lactose is the major carbohydrate present in milk, which can be seen as a crystalline or amorphous glassy condition in the solid state. The lactose content in sample GMP2 was observed significantly ( $p < 0.05$ ) lower than in sample COM. GMP1 was found non-significant ( $p > 0.05$ ) with both sample GMP2 as well as COM. The average lactose content was observed 35.14, 33.80 and 37.49% respectively in GMP1, GMP2 and COM. Higher lactose content was found in cow milk powder. The lactose content of GMP1 varied from 32.71 to 38.45% whereas 32.68 to 36.45% were found in GMP2. The lactose content of goat milk and cow milk powder is affected by various chemical reactions between the ingredients, hot air temperature, design of drying chamber, storage conditions, species and breed of animal, etc. (Seth *et al.* 2017) [33]. There were several workers reported lactose content in goat milk powder from 28.97 to 38.81%, Fonseca *et al.* 2011 [12]. Some workers also worked on cow milk powder and reported the lactose content from 33 to 40.1% (Pugliese *et al.* 2017; Magan *et al.* 2019) [28, 24].

The average chloride content in goat milk powder was found from 0.25 to 0.32%. The chloride content in cow milk powder was found to be 0.20%. The chloride content in cow milk powder was found significantly ( $p < 0.05$ ) lower than

the goat milk powder. The chloride content in GMP1 varied from 0.21 to 0.29% whereas 0.22 to 0.40% was found in GMP2. The chloride content in cow milk powder varied between 0.14 to 0.25%. Mayer *et al.* (2012) [25] studied on physical and chemical characteristics of sheep and goat milk and reported the chloride content in goat milk was 0.16 to 0.21 g/100 ml. Yoganandi *et al.* (2015) [40] observed chloride in a different breed of the camel which varied between 0.20 to 0.25% whereas 0.11% chloride content in cow milk.

Vitamin C, also called as ascorbic acid, is present in milk. Vitamin C content between the sample GMP1 and GMP2 was found non-significant ( $p > 0.05$ ) with an average value of 10.75 mg/L and 10.93 mg/L respectively. Vitamin C content in cow milk powder was found significantly ( $p < 0.05$ ) lower than goat milk powder. Vitamin C content in GMP1 varied from 9.46 to 12.04 mg/L and 9.46 to 12.04 mg/L in GMP2. The vitamin C content varied from 8.086 to 9.63 mg/L in COM. The vitamin C content in cow milk powder was found to be 8.88 mg/L. The vitamin C content of milk powder is influenced by high heat treatments, long storage of milk before drying, type of species and breeds. Stewart *et al.* (1946) reported a vitamin C content of 12.5 mg/l in fresh whole milk powder. Kumar *et al.* (2012) studied on nutritional features of goat milk and reported the vitamin C content of 12.9 mg/L in goat milk and 9.4 mg/L in cow milk.

**Table 1:** Chemical composition of goat and cow milk powder

| Parameters/ Sample | %                        |              |                           |                          |                            |                           | mg/L                      |
|--------------------|--------------------------|--------------|---------------------------|--------------------------|----------------------------|---------------------------|---------------------------|
|                    | Moisture                 | Fat          | Protein                   | Ash                      | Lactose                    | Chloride                  | Vitamin C                 |
| GMP1               | 2.81 ± 0.06 <sup>c</sup> | 28.18 ± 2.05 | 27.00 ± 1.06 <sup>b</sup> | 6.43 ± 0.15 <sup>b</sup> | 35.14 ± 2.40 <sup>ab</sup> | 0.25 ± 0.03 <sup>ab</sup> | 10.75 ± 0.86 <sup>b</sup> |
| GMP2               | 2.14 ± 0.08 <sup>b</sup> | 28.29 ± 1.68 | 29.79 ± 0.58 <sup>c</sup> | 6.45 ± 0.19 <sup>b</sup> | 33.80 ± 1.35 <sup>a</sup>  | 0.32 ± 0.07 <sup>b</sup>  | 10.93 ± 0.93 <sup>b</sup> |
| COM                | 1.84 ± 0.11 <sup>a</sup> | 30.32 ± 0.99 | 24.77 ± 0.37 <sup>a</sup> | 5.73 ± 0.18 <sup>a</sup> | 37.49 ± 0.97 <sup>b</sup>  | 0.20 ± 0.04 <sup>a</sup>  | 8.88 ± 0.58 <sup>a</sup>  |
| Sem                | 0.04                     | 0.82         | 0.36                      | 0.09                     | 0.84                       | 0.03                      | 0.40                      |
| CD                 | 0.13                     | NS           | 1.12                      | 0.27                     | 2.59                       | 0.08                      | 1.24                      |
| CV%                | 4.22                     | 6.31         | 3.00                      | 3.21                     | 5.31                       | 22.93                     | 8.82                      |

a-c: values with different letters between a row are significantly different at 5% (i.e.,  $p < 0.05$ ).

### Chemical characteristics of goat and cow milk powders

The titratable acidity of cow milk powder was found significantly ( $p < 0.05$ ) lower than both goat milk powder. The titratable acidity in GMP1 varied from 0.18 to 0.19% LA, 0.18 to 0.21% LA in GMP2 and 0.15 to 0.18% LA in COM. The average titratable acidity was observed 0.17, 0.19 and 0.20% LA in sample COM, GMP1 and GMP2 respectively. The free fatty acid content of sample GMP2 was found higher than the other two samples so this may also be the reason for higher titratable acidity in GMP2. Reported titratable acidity 0.16% LA and 0.14% LA by Reddy (2013) [30] in goat milk powder. The titratable acidity of cow milk powder was observed by various researchers between 0.15 to 0.20% lactic acid (Suliman *et al.* 2014) [36]. According to Chudy *et al.* (2015) [5], the type of powder, timing, formation of lactic and formic acid and storage method such as air or vacuum all significantly influenced variations in acidity. The interaction of glucose with proteins and phospholipids may result in an increase in the acidity of the powders under analysis. An increase in the acidity of powders can result from fat oxidation, free fatty acid production, and hydrolysis. The higher titratable acidity in our finding might be due to the higher free fatty acid.

The antioxidant capacity in cow milk powder was found significantly ( $p < 0.05$ ) lower in comparison to goat milk powders. The non-significant ( $p > 0.05$ ) difference was observed between samples GMP1 and GMP2. The average antioxidant capacity was found 17.38% in cow milk powder whereas 27.72 to 30.18% inhibition observed in goat milk powder. The antioxidant capacity of GMP1 varied from 24.48 to 34.26% inhibition, whereas 24.55 to 30.66% inhibition in GMP2. The antioxidant capacity was found 15.30 to 20.53% inhibition in COM. Vitamin C content which influences the antioxidant capacity was found significantly higher in goat milk powder than the cow milk powder might be the reason of variation in antioxidant capacity. Kalyan *et al.* (2018) [19] reported antioxidant capacities of 54.86 and 56.55% in pasteurized and unpasteurized goat milk respectively. The antioxidant capacity of milk powder is found less than milk it could be due to variations in processing conditions such as preheating, evaporation and spray drying as well as different physicochemical interactions between ingredients. Antioxidant capacity of milk and milk products is mainly due to sulphur containing amino acids, phosphate, vitamins (A, E & C), carotenoids, zinc, selenium and enzyme systems (Khan, *et al.* 2019) [21].

The free fatty acids content are precursors of oxidation reactions producing aldehydes and ketones, compounds responsible for flavours in milk powder such as oxidized, metallic and tallowy. The free fatty acids content of GMP1 was observed non-significant ( $p > 0.05$ ) with COM. The free fatty acid content of GMP2 was found significantly ( $p < 0.05$ ) higher than both GMP1 and COM. The average value of free fatty acid in GMP1 was found 2.02% oleic acid. An average FFAs content in GMP2 was found 3.34% oleic acid. The FFAs content in sample GMP2 observed from 2.70 to 3.85% oleic acid. FFAs content in COM was ranged between 2.10 to 2.61% oleic acid. The variation in average value of free fatty acid in all the samples might be due to variations in the fat content of these powders and various processing treatments given by different manufacturers (Paez *et al.* 2006) [26]. Fonseca *et al.* (2013) [13] reported 5.9 to 10.1 in mEq/kg of powder in goat milk powder during the study on storage of refrigerated raw goat milk affecting the quality of whole milk powder.

The peroxides are products of primary lipid oxidation. The peroxide value was found significantly higher in cow milk powder with the average value of 0.94 mEq/kg fat. Peroxide value in goat milk powder was found 0.29 to 0.44 mEq/kg fat. The peroxide value of GMP1 varied from 0.26 to 0.32 mEq/kg fat, 0.402 to 0.48 mEq/kg fat in GMP2 and in COM 0.82 to 1.07 mEq/kg fat. Variation in the peroxide value might be due to differences in fat content, factors such as concentration, conditions of drying as an air inlet and outlet temperature and absolute humidity and temperature. The higher peroxide value is a result of an accumulation of oxidised lipid intermediates whereas a drop in the peroxide

value in the sample might be attributed to more oxidation with the creation of small molecules including acids, ketones, and aldehydes (Thomas *et al.* 2004). FFAs content, packaging materials and storage conditions also affect the peroxide value of milk powder. Reported a peroxide value of 4.89 mEq/kg fat in goat milk powder and 9.85 mEq/kg fat in cow milk powder. Fonseca *et al.* (2013) [13] reported 0.1 to 0.2 mEq/kg fat in goat milk powder and Davis *et al.* (2017) reported 0.099 to 0.107 mEq/kg fat for goat milk powder.

The TBA value indicates the degree of the TBA reactive substances, a group of substances that are products of lipid peroxidation and are generated by the further degradation of lipid hydroperoxides. TBA value is called as the measure of secondary oxidation. The significantly ( $p < 0.05$ ) highest TBA value was observed in GMP2. Sample GMP1 was found non-significantly ( $p > 0.05$ ) different from sample COM. The average TBA value was found in GMP1, GMP2 and COM 0.029, 0.061 and 0.015 respectively. TBA values of GMP1, GMP2 and COM varied from 0.018 to 0.043, 0.014 to 0.097 and 0.009 to 0.018 respectively. The variation in fat content, difference in storage condition, lipid oxidations, amounts of aldehydes and ketones present in the powder that reacts with 2-thiobarbituric acid might be the reason behind the variation in the TBA value among the powder sample. Li *et al.* (2019) worked on a comparative study on the characteristics and oxidation stability of commercial milk powder and observed the TBA value of whole milk powder 0.044 for the fresh sample. Chudy *et al.* (2015) [5] reported a 0.02 TBA value in whole milk powder.

**Table 2:** Chemical characteristics of goat and cow milk powder

| Parameters/Sample | Titratable acidity (%LA) | Antioxidant capacity (% inhibition) | Free Fatty Acids (% OA)  | Peroxide value mEq/kg fat | TBA values at 538 nm       |
|-------------------|--------------------------|-------------------------------------|--------------------------|---------------------------|----------------------------|
| GMP1              | 0.19 ± 0.00 <sup>b</sup> | 30.18 ± 3.61 <sup>b</sup>           | 2.02 ± 0.16 <sup>a</sup> | 0.29 ± 0.02 <sup>a</sup>  | 0.029 ± 0.011 <sup>a</sup> |
| GMP2              | 0.20 ± 0.01 <sup>b</sup> | 27.72 ± 2.02 <sup>b</sup>           | 3.34 ± 0.48 <sup>b</sup> | 0.44 ± 0.03 <sup>b</sup>  | 0.061 ± 0.037 <sup>b</sup> |
| COM               | 0.17 ± 0.01 <sup>a</sup> | 17.38 ± 1.80 <sup>a</sup>           | 2.33 ± 0.17 <sup>a</sup> | 0.94 ± 0.10 <sup>c</sup>  | 0.015 ± 0.003 <sup>a</sup> |
| Sem               | 0.00                     | 1.33                                | 0.15                     | 0.03                      | 0.01                       |
| CD                | 0.01                     | 4.09                                | 0.47                     | 0.09                      | 0.03                       |
| CV%               | 4.68                     | 11.84                               | 13.32                    | 12.21                     | 71.75                      |

<sup>a-c</sup>: values with different letters between a row are significantly different at 5% (i.e.,  $p < 0.05$ ).

#### Heat load indicators of goat and cow milk powder

The higher free HMF content was observed in cow milk powder with an average value of 2.74 µmol/L compared goat milk powder. The free HMF content in goat milk powder was varied between 0.57 to 1.80 µmol/L. The free HMF content in GMP1 varied from 0.01 to 1.38 µmol/L whereas 0.90 to 3.00 µmol/L in GMP2 and 2.11 to 3.41 µmol/L in COM. The difference in the free HMF might be due to different processing parameters such as preheating, evaporation and spray drying as well as technology used by different manufacturers (Patton, 1955) [27]. The rate of solid state early Maillard reaction is strongly dependent on water activity as well as the ratio of protein to lactose initially present lower ratios react faster than the higher ones. Free HMF of milk powder depends on numerous factors including water activity (aw), enzyme reactions, contact time of hot air with the milk particles, temperature and the physico-chemical state of the component's, ratio of protein and lactose, hot air temperature, pH and design of drying chamber, etc. Reported 4.45 µmol/L, free HMF content for whole milk powder whereas 8.42 µmol/L for infant formula.

Free HMF content in SMP was observed to be 4.95 µmol/L by Hameed *et al.* (2019) [17].

The significant ( $p < 0.05$ ) variation was observed in total HMF content between goat milk powder and cow milk powder. The average total HMF content in cow milk powder was found 16.85 µmol/L and in goat milk powder varied between 4.64 to 9.38 µmol/L. The highest total HMF content was found in cow milk powder with. Total HMF content was observed 0.88 to 9.80 µmol/L in GMP1, 3.68 to 17.85 µmol/L in GMP2 and 14.62 to 20.21 µmol/L in COM. The variation in the total HMF might be due to different processing parameters such as preheating, evaporation and spray drying as well as technology used by different manufacturers (Patton, 1955) [27]. Total HMF of milk powder is affected by physicochemical changes in the sample, enzyme reactions, the ratio of protein and lactose, hot air temperature, design of the drying chamber, contact time of hot air with the milk particles, packaging material used, storage conditions, etc (Czerwonka *et al.* 2020) [6]. Rehman *et al.* (2000) [31] worked on HMF as an indicator for the detection of dried powder in liquid milk and found 28.00

$\mu\text{mol/L}$  for skimmed milk powder. The total HMF content of  $7.25 \mu\text{mol/L}$  was observed in whole milk powder by Chudy *et al.* (2015) [5]. Worked on whole milk powder and reported a total HMF content  $4.45 \mu\text{mol/L}$ . Hameed *et al.* (2019) [17] found  $4.95 \mu\text{mol/L}$  total HMF in SMP.

The lactulose content in samples GMP1, GMP2 and COM was found to be 123.86, 347.27 and  $577.57 \text{ mg/L}$  respectively. The higher lactulose content was found in cow milk powder compared to goat milk powder. Lactulose content in GMP1 varied from 121.22 to  $126.12 \text{ mg/L}$  whereas 345.71 to  $351.30 \text{ mg/L}$  were found in GMP2 samples. The lactulose content in sample COM ranged between 571.70 to  $583.59 \text{ mg/L}$ . The variation in the lactulose contents among the different powders might be due to differences in lactose concentrations, different concentration of feeding. Some authors stated that higher rate of lactulose formation was observed in alkaline conditions whereas lower in the case of acidic condition. The acidity of goat milk powders is higher than that of cow milk powder which is directly related to the higher lactulose concentration in cow milk powder. Adhikari *et al.* (1991) [2] reported a lactulose content of 474.30 to  $479.80 \text{ mg/100 g}$  in roller dried milk powder and 261.40 to  $268.34 \text{ mg/100 g}$  in

spray dried milk powder. The lactulose content in infant formula was found  $831.6 \text{ mg/L}$  by Guerra-Hernandez *et al.* (2002).

The significant ( $p < 0.05$ ) higher whey protein nitrogen index was observed in the cow milk powder than goat milk powder. The WPNI was found to be  $5 \text{ mg/g}$  of powder in goat milk powder and  $8.40 \text{ mg/g}$  of powder in cow milk powder respectively. WPNI of GMP1 was varied from 3.88 to  $6.42 \text{ mg/g}$  powder, 4.01 to  $5.71 \text{ mg/g}$  powder in GMP2, and 7.15 to  $9.98 \text{ mg/g}$  powder in COM. WPNI is influenced by time and temperature combination used during evaporation and pasteurization, seasonal variations, and perhaps protein standardization and concentration of feeding. McKenna *et al.* (1999) reported 1.1 to  $1.8 \text{ mg/g}$  WPNI in whole milk powder. American Dairy Products Institute (ADPI, 2002) specified milk powder as low heat powder which has WPNI 6 or more than 6, medium heat milk powder have WPNI between 1.51 to 5.99 and high heat powder should have a 1.5 or less than that WPNI. Magan *et al.* (2019) [24] found WPNI in whole milk powder 3.8 to  $4.2 \text{ mg/g}$  of powder. Zouari *et al.* (2021) [42] found  $9.6 \text{ mg/g}$  of powder WPNI in cow milk powder.

**Table 3:** Heat load indicators of goat and cow milk powder

| Parameters/Sample | Free HMF ( $\mu\text{mol/L}$ ) | Total HMF ( $\mu\text{mol/L}$ ) | Lactulose ( $\text{mg/L}$ ) | WPNI ( $\text{mg}$ ) |
|-------------------|--------------------------------|---------------------------------|-----------------------------|----------------------|
| GMP1              | $0.57 \pm 0.63^a$              | $4.64 \pm 4.08^a$               | $123.86 \pm 1.79^a$         | $5.00 \pm 1.05^a$    |
| GMP2              | $1.80 \pm 0.95^b$              | $9.38 \pm 6.84^a$               | $347.27 \pm 2.34^b$         | $5.00 \pm 0.67^a$    |
| COM               | $2.74 \pm 0.54^b$              | $16.85 \pm 2.41^b$              | $577.57 \pm 4.48^c$         | $8.40 \pm 0.98^b$    |
| SEm               | 0.36                           | 2.40                            | 1.55                        | 0.46                 |
| CD                | 1.12                           | 7.40                            | 4.77                        | 1.41                 |
| CV%               | 47.86                          | 52.22                           | 0.99                        | 16.64                |

<sup>a-c</sup>: values with different letters between a row are significantly different at 5% (*i.e.*,  $p < 0.05$ ).

## Conclusion

Thus, from the study of chemical composition it is observed that goat milk powder has higher in moisture content, protein content, vitamin C content, ash content including chloride content and less fat content, lactose content than cow milk powder. The cow milk powder has higher fat content, lactose content than goat milk powders. Study of chemical characteristics and heat load indicators also revealed that the goat milk powder has higher in antioxidant capacity, titratable acidity, free fatty acid and TBA value compared to cow milk powder. The peroxide value, free HMF, total HMF, lactulose content and WPNI was found higher in cow milk powder than goat milk powder. Short-term storage causes the peroxide value to rise, whereas long-term storage causes it to fall. Increased lipid oxidation in a dried product can have negative effects on flavour, colour, and vitamin content. Oxidation reduces a product's shelf life, degrades its quality, and makes it less acceptable to consumers. This reaction also raises concerns about food safety because it reduces the availability of milk protein's essential amino acid residues when linked to lactose. So, it is important to assess the peroxide value, free fatty acids content, TBA value and HMF content in milk powder.

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