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A Comparison Between Goat and Human Milk in Infant Feeding

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ABSTRACT

Goat milk is an ideal replacement for cow milk. Comparing goat milk with human milk was examined in order to evaluate its nutritional values with respect to infant feeding. It was observed that goat milk characterized with higher acidity, total solids, protein, fat, ash, energy value, and mineral contents, and lower lactose and pH than human milk. The nitrogen distribution presented Evident differences in the nitrogen distribution in two species, especially in the ratios of nitrogen distribution, such as NPN/TN, WN/TN, WPN/CN and CN/TN. The amino acid profile of the two proteins considerably varied. Generally, the amino acid pattern of goat milk proteins satisfactory balance of essential amino acids content for the infant diet. The composition of fats was well-differentiated, mainly as the content of medium-chain fatty acids, which were higher in the goat milk. Human milk, on the other hand, contained higher levels of the long chain fatty acids. It could also be concluded that goat milk could be considered as a good food of high nutritive value, but when using goat's milk to feed infants, it should be diluted to reduce the protein and mineral content, alter the milk protein ratio by increasing the whey protein, and to raise the Ca: P ratio from 1.2 to 2.0. It could also be added that carbohydrates, vegetable oils and vitamins are of importance, to ensure the goat's milk is a suitable for infants' consumption.

Keywords: goat milk, human milk, infant feeding, chemical composition, minerals, nitrogen fraction, amino acids, fatty acids.

INTRODUCTION

Human milk is regarded as one of the best food for the infant in nature in terms of nutrition, immunology and food safety. But, time limits, health conditions, and urban development may lead to the early end of breastfeeding. Consequently, a demand for substitution feeding source is mandatory for those babies who cannot have mothers' milk. This alternative is necessary to create more nutritionally suitable products that are homologous to human milk for the feeding of infants by simulating the macronutrients in natural milk with human milk. The increased incidence of allergies of cow's milk proteins (CMP) in newborns in recent years, The interest of the scientific research was aimed at enhancing the milk of other species, as substitute for breast milk and bio-functional food. Compared to human or cow milk, goat milk is reported to have specific biologically active characteristics such as high digestibility, high buffering capacity, distinct alkalinity and addition to therapeutic values in human nutrition and medicine (Vandenplas et al. 2014, Lessen and Kavanagh, 2015, Park 2017).

Goat milk has been advised as a suitable replacement for cow milk and has become a more popular alternative infant food. Goat milk was estimated to contribute about 2.4% of the worldwide milk production. Goat milk can impedes stomach ache, digestibility troublesome, and asthma compare to cow's. A study to differentiate between goat's and cow's milk in mice was conducted and confirmed that goat's milk is decreasing particular agents contribute to allergy symptoms. Goat branch has improved remarkably through the previous decade. From 1990 till 2017 the numbers of goat farm have increased by 76% and the goat milk production increased by 83.4%. It is considered the greatest increase in animal number and goat milk production tonnage compared to other farm animals. More clinical and nutritional experiments on human volunteers are needed to support and confirm the documented nutritional, hypoallergenic and therapeutic value of goat milk in the nutrition of human (McCullough 2003, Lara-Villoslada *et al.* 2004, Maduko 2007, Park 2012 and FAO 2018).

Therefore this study aimed to evaluate the composition and nutritional value of goat's milk in comparison to human milk for infant feeding.

MATERIALS AND METHODS

Goat milk was collected from El-Serw Animal Production Research Station, Agricultural Research Center, Egypt. Human milk samples were collected from different volunteer mothers at different lactation stages.

pH values were determined by using a digital pH meter (Jenway 3305, England). Titratable acidity was measured by titration with NaOH (0.1N) using phenolphthalein indicator. Moisture content, total solids, fat, total protein and ash were measured according to AOAC (1990). While, lactose content was calculated by the difference between total solids and (protein+ fat+ ash) .

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The concentrations of non protein nitrogen (NPN), total nitrogen (TN) and non casein nitrogen (CNN) were detected by Kjeldahl method according to Guo *et al.* (2007). Rest of nitrogen fractions was calculated as:

Casein N = TN – NCN

Whey N = NCN – NPN

For calculating milk protein content and other protein fractions, the nitrogen conversion factor of 6.38 was used.

Energy values were calculated by multiplying protein, fat and lactose contents by factors of 4.27, 8.79, and 3.87 kcal/g, respectively (Food and Nations 2003).

Concentrations of minerals were measured by means of I.C.P Spectrophotometer Thermo Jarrel Ash model POEMS 3, using 1000ppm (Merck) Stock solution for standard preparation.

Determination of amino acid profile was carried by weighing one gram of milk sample in a thin hydrolysis tube, and by adding 5 ml of HCL 6N. The tube was closed tight and was incubated at 110o C for 24 hours. The mixture was filtrated and evaporated at 140o C for one hour, finally, 1 ml of the diluted buffer was added to the dried filtrate sample. Amino Acid Analyzer (Sykam S 7130 Amino Acid Regent Organizer) was used to analysis amino acid composition.

Fatty acids of milks were analyzed by gas chromatography according to AOAC official method of analysis (2016).

Statistical analysis was done using the MSTAT-C (ver 2.10, USA.) package on a personal computer. All experiments were performed in triplicates. Differences were considered to be significant at ($P < 0.05$).

RESULTS AND DISCUSSION

Physico-chemical properties of human and goat milks are illustrated in Table (1). Statistical analysis indicated highly significant differences ($P<0.001$) in almost all of the tested parameters between human and goat milk.

Table 1. Physico-chemical characterizations (%)of human and goat milks.

	Human milk	Goat milk
Acidity	0.07±0.01[b]	0.17±0.01[a]
PH	7.04±0.17[a]	6.64 ±0.05[b]
Total Solids	12.11±0. 44[b]	12.90±0.46[a]
SNF	8.435±0.34[b]	8.844±0.35[a]
Fat	3.67±0. 49[b]	4.06±0.23[a]
Protein	1.13±0.12[b]	3.43±0.25[a]
Lactose	7.05±0.43[a]	4.67±0.21[b]
Ash	0.26±0.09[b]	0.75±0.04[a]
Total energy(kcal/100ml)	67.68±4.18[b]	74.85±2.98[a]

Means with unlike superscript letters were significantly different (α =0.05). SNF, solid not fat.

Results presented in Table (1) illustrate higher titratable acidity of goat milk than that of human milk ($P<0.001$) due to the presence of lactic acid, citric acid and phosphoric acid (Mahmood and Usman, 2010). The result also showed that the pH average values of human and goat milk was of 7.04 and 6.64, respectively. pH values of human milk were significantly ($p<0.001$) higher than that of goat milk. This might be explained by the low casein and phosphate contents of human milk. These results are in agreement with (Shenana *et al.* 2014) and (El-Hatmi *et al.* 2015). The total solids (TS) recorded 12.11 and 12.90 g/100ml for human and goat milk, respectively. Significant differences were observed ($p<0.01$) between TS of human and goat milk. However, the TS content of human milk was higher than that reported by Shamsia (2009), and lower than that reported by Soliman (2005) and similar to that reported by Soliman *et al.* (2014) which could be due to the different stage of lactation feeding system , individual variations and nutritional habits of mothers. On the other hand, higher TS was detected in goat milk than that reported by Teleb *et al.* (2016) and Khanam (2019); and lower than that reported by Rafiq *et al.* (2016).

Significant differences ($p<0.001$) were observed between goat and human milks in the concentration and types of proteins and ash. Goat milk contained 3 times greater levels of protein and ash than human milk. According to these results, the average total protein content of 3.43 and 1.13g/100ml for goat and human milk were detected, respectively. This is because the amount of protein in milk is linked to the growth rate of the species. The low protein content of human milk results in low milk buffering capacity and osmotic stress for kidney function in newborn or young infant. Several findings concerning the protein content of human and goat milk proteins which have shown harmony with present research work. Amount of ash content found in goat milk was in agreement with that reported by (Ebtehag *et al.* 2015; Mahmood and Usman 2010; Khanam, 2019), but lower than that reported by (Soliman 2005; Park 2017; Rafiq *et al.* 2016). Amount of ash content found in human milk during this study was in line with the findings of Räihä 1993, Ogbu 2003 Soliman *et al.* 2014; Shenana *et al.* 2014, Soliman, 2005, Shenana *et al.* 2014; Soliman, 2005; Shamsia, 2009, Rafiq *et al.* 2016, *Park et al.* 2007 and Soliman, 2005).

The lactose content in human milk (7.05%) was higher than that in goat milk (4.67%) at highly significant ($p<0.001$) level. It is well known that lactose, including galactose, a constituent of the myelinic sheath of the central nervous system cells. Furthermore, lactose is beneficial to infants as it helps with absorption of minerals and promotes the growth of good bacteria (Guo, 2014). Results indicated that goat milk had higher calorific value (75.85) than human milk (67.75) at highly significant ($p<0.001$) level, due to its higher protein and fat content.

Data presented in Table (2) illustrates the distribution of nitrogen in human and goat milk (g/100ml). Goat milk consist of higher significant ($p<0.001$) levels of T.N and C.N but lower level of W.N than human milk. The casein content of goat milk is (2.56%) more than 6 times greater than that (0.40%) of human milk. These results are in harmony with those reported (Park 2017; Shamsia 2009; Shenana *et al.* 2014) especially for human milk.

Non-significant ($p>0.05$) variation in the NCN, NPN, WN fractions and whey protein between the human and goat milk. These fractions occurs in approximately equal concentrations in both milks. The NCN content determined was 144 mg/100ml in human milk. Similarly, in goat milk, mean of NCN was 137±27 mg/100ml. On the other hand, NPN was 40 mg/100ml in both milks. Whey protein nitrogen and whey protein recorded (103 and 65 mg/100ml) and (98 and 62 mg/100ml) for human and goat milk, respectively, which came in harmony with those results obtained by Shenana *et al.* (2014), and goat milk proteins (Rafiq *et al.* 2016; Park, 2007; Ebtehag *et al.* 2015) have shown harmony with present research data.

Table 2. Nitrogen distribution of human and goat milk (mg/100ml).

	Human milk	Goat milk
TN	206±23[b]	538±24[a]
NCN	144±24	137±27
NPN	40±7	40±15
NPN/TN (%)	19.61±2.16[a]	7.37±2.78[b]
CN	62±8[b]	401±4[a]
CN /TN (%)	30.57±5.56[b]	74.43±5.48[a]
WN	103±20	98±3
WN/TN (%)	49.82±4.07[a]	18.20±5.20[b]
Casein	0.40±7[b]	2.56±36[a]
whey protein	0.65±0.14	0.62±0.49
Casein /Whey ratio	38: 62[b]	80: 20[a]

Means with unlike superscript letters were significantly different (α =0.05). TN, total nitrogen; NCN, non-casein nitrogen; NPN, non-protein nitrogen; CN, casein nitrogen; WN, whey nitrogen.

On the contrary, the ratios of nitrogen, such as NPN/TN, CN/TN and WN/TN, showed highly significant differences in the two species (P<0.001). The ratio of NPN/TN contents of the human milk was measured to be significantly higher (19.61% to total protein) than those of the goat milk (7.37%). Nutritionally, it is an important fraction because it could be easily used for the synthesis of nerve tissues and neurotransmitters. (Csapo 2009). The lower CN/TN (31%) and higher WN/TN (49.7%) in human milk, it results in soft coagulum, following milk ingestion and increased digestibility and absorption of soluble proteins, make it highly nutritious for newborns (Fox and McSweeney, 1998).

The ratio of casein to whey in goat (80:20) and human milks (38:62) were extremely different, and to humanize this ratio, some of the available commercial infant formulas are fortified with whey proteins (Maduko *et al.* 2007). The obtained results are in agreement with those of (Maduko *et al.* 2007; Shenana *et al.* 2014).

Mineral contents of human and goat milk are listed in Table (3). Milk minerals are considered essential having well-known biological functions, i.e.,structural components of body tissue and components of several enzymes and other biologically active compounds (Fantuz *et al.*, 2016). It is well known that changing the environment has a significant effect on the physiological function of both human and animals. Concentration of minerals in human and goat milk depends on breed, period of lactation and dietary content (ICAR, 1981). Statistical analysis showed highly significant differences (P<0.001) in most minerals in both tested milks (Table. 3).

Results obtained in the present study confirmed that goat milk is of the highest mineral contents, compared to human milk with significant differences (P<0.001) between them. The concentrations of Ca, P, K, Mg, Mn, zn, Na and Cl were represented by 4.7, 7.6, 4.1, 3.1, 3.8, 1.4, 3.4 and 2.8 times their human milk concentration. So, goat milk can be regarded as a good supply of these minerals. A significant effect of goat milk consumption is attributed to mineral bioavailability, as showed in rat studies (Díaz-Castro *et al.* 2015).

Table 3. Minerals content of human and goat milk (mg/100ml).

	Human milk	Goat milk
Ca	29.27±4.16[b]	136.30±13.90[a]
P	14.46±1.07[b]	111.29±19.01[a]
Ca/P	2.02±0.31[a]	1.26±0.27[b]
Cu	0.05±0.02	0.05±0.02
Fe	0.06±0.614	0.06±0.03
K	55.94±3.90[b]	173.08±24.21[a]
Mg	3.82±0.78[b]	15.62±1.70[a]
Mn	0.05±0.04	0.17±0.48
Zn	0.28±0.10[b]	0.38±0.11[a]
Na	14.01±2.46[b]	47.84±5.45[a]
Cl	56.50±8.24[b]	158.00±8.21[a]
Li	0.25±0.12	0.31±0.06

Means with unlike superscript letters were significantly different α =0.05).

Human milk had significantly lower content (p<0.001) of Ca and P that of goat milk (29.27 and 14.46% vs. 136.3 and 111.29%), respectively. The low levels of Ca and P in human milk were due to the low protein content, particularly, casein of this milk (Goedhart and Bindels 1994). In contrast, human milk contained the highest significant differences Ca:P ratio 2.02:1 versus 1.26:1 for goat milk at (P<0.001). The Ca:P ratio of human and goat milk agrees with (Soliman, 2005 and Shenana *et al.* 2014).

Higher significant differences were also observed regarding the examined elements were found (p<0.001) in K (55.94 and 173.08), Mg (3.82 and 15.86), Na (14.01and 47.84) and Cl (56.50 and 158) mg/100ml in human and goat milk, respectively. Similar results were obtained by (Soliman, 2005; Shenana *et al.* 2014).

No significant differences (P>0.05) in some trace elements as Cu , Fe, Mn and Li in both goat's milk and human milk and differences in Zn at (p< 0.05). This may be due to the larger proportions of most of these elements bound to whey protein (Fransson and Lönnerdal 1983). This might most probably be described by a significantly similar concentration of whey in human milk and goat milk.

Goat milk contains higher concentrations of certain minerals, and in case of feeding the infants, may lead to risk of hypertonic dehydration (Maduko *et al.* 2007). Should it feed infants, milk should be diluted to about three-quarter strength, thus reducing the remaining components that need to be modified

Concentrations of the essential and non-essential amino acids composition (g/100 g amino acids) recovered in human and goat milks are presented in Table (4). In addition to the eight essential amino acids identified for adults, some of the other is considered to be essential for infant. As the inter-conversion mechanisms of tyrosine from phenylalanine, cystine from methionine and histidine from ribose-5-phosphate aren't completely developed in infant, due to the reduced activity or non-presence of their specific convertases, they are also considered to be essential to infant (Thompkinson and Kharb 2007). Even though low protein in human milk, all eleven essential amino acids are supplied according to the requirements of infants (Thompkinson and Kharb 2007).

Statistical analysis indicated highly significant differences in almost all of the amino acids of human and goat milk. The group of essential amino acids in human milk (50%) noteworthy differs (p<0.001) from goat milk

(45.37%). Human and goat milks are rich in all essential amino acids excepting methionine. These findings are in agreement with that reported by (Sabahelkheir *et al.* 2012). Human milk was characterized by high contents of histidine, leucine and isoleucine. On the other hand, goat milk proteins contributed over methionine and phenylalanine to the milk as do the human milk proteins. There were no significant differences (p>0.05) in lysine, threonine, valine, cystine and arginine in both milks.

Table 4. Amino acid composition (g/100 g amino acids) of human milk and goat milk.

	Human milk	Goat milk
Essential amino acids		
Lysine	7.90±0.06	8.28±0.67
Methionine	0.53±0.14[b]	2.18±0.44[a]
Phenylalanine	3.94±0.03[b]	4.87±0.23[a]
Threonine	4.82±0.12	4.89±0.25
Histidine	8.93±0.61[a]	3.38±0.78[b]
Leucine	10.94±0.32[a]	9.64±0.10[b]
Isoleucine	6.12±0.31[a]	4.95±0.19[b]
Valine	6.80±0.20	7.18±0.85
Total	50±0.90[a]	45.37±2.17[b]
Nonessential amino acids		
Aspartic acid	10.23±0.41[a]	7.40±0.14[b]
Serine	4.73±0.06[b]	4.90±0.12[a]
Glutamic acid	19.00±0.41[b]	20.48±0.69[a]
Alanine	4.50±0.26[a]	3.04±0.37[b]
Cystine	0.21±0.14	0.55±0.49
Tyrosine	1.39±0.28[b]	3.59±0.82[a]
Arginine	3.21±0.05	4.51±1.92
Glycine	2.60±0.07[a]	1.90±0.09[b]
Proline	4.15±0.32[b]	8.18±2.72[a]
Total	50±0.90[b]	54.54±2.17[a]

Means with unlike superscript letters were significantly different (α =0.05).

There are high differences (p<0.001) in total non-essential amino acids between human milk (50%) and the goat milk (54.45%) as shown in a (Table 4). The major of non-essential amino acid was glutamic acid while cystine was present in the lowest concentration in the two species. In general, goat milk protein amino acid pattern have indicated that they have a sufficient quality ratio of essential amino acids for the human diet or surpass the amino acid requirements of FAO / WHO / UN (1985). These results are in agreement with that reported by (Haenlein 2004).

This difference in amino acids between the two species is due to Two-thirds of human milk proteins belong to the whey protein group, so the amino acid composition of human milk varies considerably from that of goat's milk, where the casein content is much higher than the whey content of goat milk (Scapo, 2009)

Data observed in Table (5) shows the fatty acid profile of human and goat milk (g/100 g total fatty acids). Goat milk fat contained higher total saturated fatty acids than uman milk fat at (p<0.001) except luric, palmatic and arachidic acids there were no significant differences at (p>0.05). Goat milk fat contained small quantities of short chain fatty acids (C4 –C6), whereas fat was free of C4, C6 and has traces of C8 in human milk. Human milk contained higher levels of all long chain fatty acids (P < 0.001) than goat milk except for myrisoleic which was higher (P<0.001) in the later.

Table 5. Fatty acid profile (g/100 g of total fatty acids) of human and goat milk fats.

fatty acids		Human milk	Goat milk
Saturated fatty acid (SFA)			
Butyric	C4:0	0	1.35±1.52
Caproic	C6:0	0	1.33±1.02
Caprylic	C8:0	0.07±0.10[b]	2.37±1.14[a]
Capric	C10:0	1.01±0.62[b]	10.61±2.73[a]
Lauric	C12:0	5.23±1.12	5.16±1.94
Myristic	C14:0	7.12±1.32[b]	10.99±1.90[a]
Pentadecamic	C15:0	0.29±0.04[b]	1.23±0.27[a]
Palmitic	C16:0	27.06±3.14[b]	29.71±3.10[a]
Margaric	C17:0	0.31±0.03[b]	0.86±0.44[a]
Stearic	C18:0	5.38±0.70[b]	11.19±5.44[a]
Arachidic	C20:0	0.19±0.01	0.10±0.09
Total (SFA)		46.18±3.66[b]	74.73±5.39[a]
Saturated fatty acid (SFA)			
Myrisoleic	C14:1	0.24±0.07[b]	0.55±0.34[a]
palmitoleic	C16:1	2.05±1.23[a]	1.00±0.64[b]
oleic acid	C18:1	34.29±2.68[a]	21.82±4.23[b]
linoleic	C18:2	14.67±2.18[a]	2.01±1.29[b]
linolenic	C18:3	1.71±1.34[a]	0.18±0.32[b]
Arachidonic	C20:4	0.04±0.08	0.04±0.05
Total (USFA)		52.83±3.38[a]	25.10±5.25[b]
Short-chain	(C4-6)	0[b]	2.69±1.82[a]
Medium-chain	(C7-12)	6.31±1.7[b]	18.3±5.24[a]
Long-chain	(C13- 21)	92.78±2.02[a]	79.13±5.71[b]

Means with unlike superscript letters were significantly different (α =0.05).

Palmitic acid was the dominant saturated fatty acid in human and goat milk which represented about 24 % and 29.7 of the total milk fatty acids, respectively. Oleic acid constituted about 94 % of the monounsaturated fatty acids and about 34.29 % of the total fatty acids presented in human milk. On the other hand, goat milk is a comparatively poor supply of essential fatty acids (Maduko 2007), and contains approximately three-quarters of saturated fatty acids. It would, therefore, be necessary to develop products that are highly nutritious, suitable and homologous to human milk fat for infants by adjusting the composition of goat milk fat to make it more similar to that of human milk. consequently, when using goat's milk to feed infants, it should be fortified with vegetable oils that feature a long chain of fatty acids.

CONCLUSION

Goat milk is different in composition from human milk and to compensate for infant feeding its composition should be manipulated to lower minerals and protein content without loss of biological quality and to modify the fat composition of the milk. Milk casein-whey protein ratio should be changed by adding the whey proteins. Also, the Ca:P ratio should be increased from 1.2 to 2.0. Goat milk should also be fortified with other nutrients as vegetable fats that feature a long chain of fatty acids, carbohydrates, and vitamins to resemble that of human milk.

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مقارنة بين لبن الماعز ولبن الام في تغذية الرضع

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دراسة إمكانية إستخدام لبن الماعز كبديل مناسب للبن البقري في تغذية الرضع، ومقارنة تركيبه بلبن الأم لتقييم قيمته الغذائية بالنسبة للرضع. وقد لوحظ أن لبن الماعز يحتوي على حموضة، مواد صلبة كلية، بروتين، دهن، رماد، وطاقة أعلى، فى حين يحتوي على نسب منخفضة في كل من اللاكتوز و pH مقارنة بلبن الام. كما كانت هناك إختلافات واضحة فى توزيع المركبات الأزوتية مثل NPN / TN و WN / TN و WPN / CN و CN / TN . بالإضافة إلى بعض الإختلافات فى المحتوى من الاحماض الامينية. وقد تميزت الاحماض الأمينيه بلبن الماعز بجودتها وتوازنها بما يكفى للنظام الغذائي للرضع. كما تبين هناك اختلاف كبير فى المحتوى من الاحماض الدهنية بين النوعين، خاصة فيما يتعلق بمحتوى الأحماض الدهنية متوسطة السلسلة، والتي كانت أعلى في لبن الماعز. بينما يحتوي لبن الأم على مستويات أعلى في جميع الأحماض الدهنية الاساسية طويلة السلسلة . وأمكن استنتاج أن لبن الماعز يمكن اعتباره غذاءًا جيدًا عالي القيمة الغذائية فى حين يلزم تخفيفة لتقليل محتواه من كل من البروتين والمحتوى المعدنى وتعديل المحتوى من البروتين ببروتينات الشرش، وتعديل نسبة Ca: P من 2.1 إلى 1.2 ، وإضافة الكربوهيدرات والزيوت النباتية والفيتامينات. وذلك لضمان أن يصبح لبن الماعز مناسب لتغذية الاطفال الرضع.