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CAMEL MILK : A POSSIBLE BOON FOR TYPE 1 DIABETIC PATIENTS

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Abstract

Poor nutrition in utero and in early life combined with over nutrition in later life may also play a role in epidemic of diabetes. The efficacy of camel milk consumption as an adjunct to routine diabetic management in type 1 diabetes is a approach showing new rays of hope to cope with this disorder by adding a food supplement with medicinal values. Research on the beneficial aspects of camel milk has been taking place in different corners of globe since last three decades. Continuous efforts to disclose the role of camel milk in diabetes has rendered it title of 'white gold'. Biochemical studies has revealed the components e.g. insulin like protein, lactoferrin, immunoglobulins are responsible for imparting camel milk the scientific weightage. In parallel, epidemiological surveys stating low prevalence of diabetes in communities consuming camel milk clearly indicate towards its hopeful role in maintaining hyperglycemia. This article shades light on camel milk production, composition, characteristics as well as it expresses positive effect of camel milk on blood glucose level, insulin dose, beta cell function. This review also compiles various epidemiological studies carried out to bring forth utility of camel milk suggesting it as a useful food supplement or alternative therapy for type 1 diabetic patients.

Key words: Camel milk, Diabetes, Raica, glycemic control, insulin.

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INTRODUCTION

Type 1 diabetes mellitus is an organ specific autoimmune disease, characterized by chronic hyperglycemia and disturbances of carbohydrates, fat and protein metabolism associated with insulin deficiency. Therefore, its primary treatment is insulin replacement. However, at present, complete physiological insulin replacement cannot be achieved, as required, in clinical practice, and metabolic disturbances of diabetes mellitus cannot be normalized. Prevention and early treatment is important because diabetes interrupts normal development and growth in children and carries the threat of severe complication in more active period of life. Incidence of diabetes appears to be increasing worldwide. Overall mortality in type 1 diabetes mellitus is almost two to seven folds compared with the matched non-diabetic population.

Composition of camel milk is different from other ruminant milk: having low cholesterol, low sugar, high mineral (sodium, potassium, iron, copper, zinc, magnesium and free calcium) (25), high Vitamin-C (28). These may act as antioxidant there by removing free radicals, which may provide a stress free situation. High concentrations of antioxidants and removal of fat from the body may enable the insulin receptors to respond better to available insulin. The milk protein lactoferrin, which is present in large quantities in camel milk, does have some anti-viral and anti-bacterial properties. Exactly how lactoferrin functions is not entirely clear, but it is known to enhance the immune response, both directly and indirectly.

Radio immunoassay of camel milk has revealed high concentration of insulin (45-128 units/litre) as compared to other milks. As is evident from literature that one of the camel milk proteins has many characteristics similar to insulin and it does not form coagulum in acidic environment (50). The lack of coagulum formation allows the camel milk to pass rapidly through the stomach together with the specific insulin like protein/insulin and remains available for absorption in intestine. Even if some insulin will be destroyed, enough amount remains available for absorption in intestine.

After research and investigations for more than decades, camel milk is now considered as a food supplement comprising medicinal values for diabetic subjects. The aim of this article is to bring forth the possible advantages of camel milk as an adjunct to insulin therapy.

CAMELS AS DAIRY ANIMALS

Milk production

Camels are normally kept and exploited in areas that are inhospitable to other dairy animals. Milk and milk products from camels are essential sources of food in vast arid and semi-arid areas of Africa and Asia, and are an important factor in the capability of the nomads to survive in and make use of these drier regions. It is difficult to see how the camel can exhibit its full genetic potential as a dairy animal under those harsh conditions.

In general, detailed milk production data are scanty because of the non-sedentary nature of the herdsmen. The lactation period varies from 8 to 18 months and total lactation yields are from 800 litres (54). As in other dairy animals, the amount of milk produced by camels varies, depending on the number of times an animal is milked, its lactation stage, the availability of pasture and water, and the presence of the calf. Available data also indicate a wide gap between nomadic average production and those of the improved and better managed herds (30). Dzhumagulov studied the potential for milk yield of bactrian and dromedary camels and hybrids from the two species. The study found that the hybrids exceeded the parents of the two species by approximately 25% (20). Hybrids from Khazakhs bactrian camels mated with dromedaries are reported to produce 40-50% more milk than the parent bactrian Khazakhs (15).

Milk secretion in the camel is stimulated by the calf which is suckled for about a year. The calves run about with their dams during the day when grazing, and are separated from their dams during the night. The amount of milk consumed by the calf is regulated by tying two or more teats, depending on the age and strength of the calf, and the milking ability of the mother. Young calves up to six months are allowed to suck two teats and are prevented from taking all the milk by binding the other teats. A string is used to tie up the teats together with a piece of sharp stick. The whole udder is covered in good lactating camels with calves over six months. This is done by covering the udder with a piece of cloth tied to the back, a sort of udder basket. If the calf dies the camel ceases to give milk, unless induced in some other ways (16).

There is sometimes an acute competition of milk between the calf and humans, especially during the drier months of the year and prolonged droughts when pastoralists experience a critical period of food shortage. A delicate balance is maintained between the amount of milk taken for human consumption and the amount left to the calf. To secure all the milk for the family, a radical decision is at times made such as slaughtering the calf. Calf monitoring is reported to be high (up to 35%) in the camel and it has been suggested that this is due to the competition for milk between the calf and man (44). The denial of colostrums to the calf by some pastoralists (33), mastitis and other diseases which reduce milk production might be contributing factors to this high level of calf mortality.

Camels are milked by hand. They are gentle and easy to handle, but handmilking a camel is not easy because of the short teats which are difficult to grasp. A thumb and one or two fingers are all that can be used. It has been shown that it is practical to milk camels by machine (14). It has also been reported that machine milked camels yielded more milk than those milked by hand (38).

Milk composition and Milk products

Milk is a supplement of protein, vitamins, mineral salts as well as calories to human diets in arid regions where some of these essentials are scarce. Camel milk is white and has a sweet taste, and could sometimes be salty, depending on the fodder. Data on the chemical composition and physico-chemical properties of camel milk have been the subject of many studies and is reviewed by Farah (23). An increase of water content in milk of dehydrated camels when compared with normally watered ones was reported by Yagil and Etzion (56). The physiological mechanism behind this phenomenon is not clear. Dahlborn and co-workers compared the effects of food deprivation on fluid balance and plasma glucose concentration among camels during pregnancy, lactation and a control period. The study found that lactating camels saved fluid by excreting concentrated urine, but milk volume was maintained during food deprivation (19).

Seasonal variation in camel milk production in pastoral production systems is great and it is believed that some surplus milk is wasted during the rainy seasons when production is high. In Khazakhistan, the annual production of camel milk is said to be approximately 4500 metric tons. Of these, approximately 62 percent is used for the production of camel Koumiss ‘shubat’, a sort of fermented milk (15). Camel milk is often consumed either fresh or in varying degrees of sourness, in the raw state without heat treatment. It is used to produce fermented milk and butter (29). Camel milk is popular among pastoralists and has been steadily gaining popularity among urban dwellers in many countries, including Saudi Arabia (22) where commercial farms are set up to supply fresh pasteurized milk to consumers (35). In Mauritania, a milk processing plant equipped with modern small-scale pasteurization equipment, was established to collect and distribute pasteurized camel milk. The industrial production of camel milk cheeses, was considered to overcome the dairy’s seasonal fluctuations in milk supply and demand (1). In addition, procedures for the manufacture of camel milk products such as ice cream (2) butter (24), soft and hard cheese (34, 37) have been studied.

Camel milk is considered a delicacy offered to guests and is believed to posses therapeutic properties among camel herding pastoralists. In Somalia, it is used as a laxative and nutritious food. In India, camel milk is believed to heal different ailments such as jaundice, tuberculosis and asthma (40). There is also an account in memoirs of Emperor Jahangir (1579-1627 AD) about usefulness and acceptability of camel milk. (41) In the former USSR it is used for treating tubetculosis (49), peptic and duodenal ulcers (45) and hepatitis (46) as well.

CHARACTERISTICS OF CAMEL MILK

Camel milk is a rich source of proteins with potential anti microbial and protective activity. Some proteins are not found in cow milk or only in minor amounts, such as the novel peptidoglycan recognition protein and the whey acidic protein or lactophorin. The special properties of camel milk have been published by several researchers. Components of camel milk differ considerably to those from ruminants (cow, sheep, goat), and have strong similarities to those of human milk. These special properties and the abundant availability of camel milk guarantees a survival under harsh conditions of the desert.

The relative amount of the main components of camel milk protein, fat and lactose are similar to cow milk (Table 1) as well as the amino acid composition of both (Table 2). The percentage of fat changes according to the water content, it is low in summer with less than 2%.

The content of niacin Vit. C is remarkably higher than in cow milk. The high concentration of Vit. C and the high water content are the most eminent factors of camel milk. In the desert, camel milk is often the only source of Vit. C since fruits and vegetables are scarce (35). The amount of the main minerals is similar in camel and cow milk. Nevertheless, variations exist due to different feeding practices. Low concentrations of copper and iron are found in dromedaries of Arabian Peninsula (52).

Insulin content in dromedary milk

Radioimmunoassay of camel milk has revealed high concentration of insulin i.e. 52units/liter (R.Singh, NRCC, Personal Communication) (48). The concentration of insulin in human milk is also high (60.23±41.05 micro u/ml), whereas it is very low in cow milk (16.32±5.98 micro u/ml) (47) but probably because of coagulation in stomach it is not available for absorption in the intestine.

In another study, the insulin content was measured in raw milk and serum of individual dromedaries over a period of 310 days. The mean milk insulin concentration was 40.5 ± 10.7 µU/ ml and the mean serum insulin concentration was

Table 1. Composition of camel milk and cow milk. Milk composition as revealed by experiments carried out at the National Research Center on Camel, Bikaner, India (42,53).

Component	Camel milk	Cow milk
Water	86-91 %	88 %
Lactose	4.2-5.0 g %	5.0 g %
Fat	2.49-3.1 g %	3.7 g %
Protein	3.78-3.9 g %	3.3 g %
Casein : albumin ratio	2.85	3.1
Sodium	38-68 mg/100ml	35-60 mg/100ml
Potassium	50-90 mg/100ml	135-155 mg/100ml
Magnesium	11.88-13.59 mg/100ml	10-15 mg/100ml
Phosphorus	41.72-47.21 mg/100ml	75-110 mg/100ml
Calcium	94.1-97.43 mg/100ml	100-140 mg/100ml
Iron	0.32-0.36 mg/100ml	0.30-0.65 mg/100ml
Zinc	1.2-6.3 mg/100ml	1.0-3.0 mg/100ml
Manganese	0.02-2.0 mg/100ml	0.01-0.03 mg/100ml
Copper	0.09-0.5 mg/100ml	0.03-0.17 mg/100ml
Vitamin A	0.03 mg %	0.34 mg %
Vitamin C	4-5 mg/100g	1.6 mg/100g
Vitamin E	0.27 mg %	0.1 mg %
Niacin	0.46 mg %	0.08 mg %
Vitamin-B_1	0.03 mg %	0.42 mg %
Vitamin-B_2	0.04 mg %	1.57 mg %

Immuno globulins: IgM, IgG, IgA and even IgD were detected in camel milk.

12.77 ± 7.62 µU/ ml. (51)

Camel milk particulars

Camel milk has the ability to inhibit the growth of pathogenic microorganisms because it contains enzymes with anti-bacterial and anti-viral properties (21). They are:

- Lactoferrin: prevents microbial growth in the gut, the amount is higher in camel milk than in cow milk
- Lactoperoxidase: contributes to the nonimmune host defence system, suppresses Gram-negative bacteria, is most effective in raw milk during the first 4 days.
- Peptidoglycan recognition protein (PGRP): broad antimicrobial activity, stimulates the immune system, possible effect on breast cancer, is higher in camel milk than in cow milk.
- N-acetyl-glucosaminidase (NAGase): anti-bacterial activity and antiviral activity.
- Lysozyme: inhibits the growth of bacteria, and has a positive influence on the storage of camel milk, but several authors have not detected it in camel milk.
- Immunoglobulins: igGs are very different to other mammals, they possess several particulars giving them tremendous advantage over conventional antibodies (27).

Camel milk does not coagulate easily. It passes the acid in stomach undisturbed, and reaches the intestines for absorption. Because the milk dose not coagulate neither with acid nor with rennet, cheese is difficult to produce.

Camel milk contains a high amount of vitamin C: 40 to 50 mg/kg compared to cow milk with 10 mg/kg. Vitamin C is a strong anti-oxidant, is essential for brain function and growth, and protects against cold. Camel milk includes insulin and is therefore used to treat diabetes mellitus. Trials in rabbits and rats showed that the insulin is not destroyed in the stomach. It passes into the intestines causing a reduction in blood sugar. Camel milk can be consumed by persons, which suffer from lactose intolerance due to the lack of the enzyme lactase.

HYPOGLYCEAMIC EFFECT OF CAMEL MILK

The efficacy of raw camel milk on glycaemic control risk factors and diabetes quality of life in patients of type 1 diabetes has been proved by several studies in different corners of world.

Effect of camel milk on blood glucose level

Various researches have advocated glucose lowering effect of camel milk. Twenty-four randomly selected patients with type 1 diabetes were enrolled in a study. These patients were divided into two groups. Group 1 (N=12) received usual care (diet, exercise and insulin) and Group 2 (N=12) received 500ml camel milk, two times daily (250ml in morning and 250ml in evening) in addition to usual care for 3 months. Frequent blood sugar monitoring was done to maintain euglycemia by titrating the doses of insulin. HbA1c, Lipid profile, Plasma insulin and C-peptide estimation, were done at the beginning and after 3 months. After 3 months of treatment there was a significant improvement in fasting blood sugar (10). Camel milk

Table 2. Amino acid composition of camel milk and cow milk (55).

Amino Acid (g/100 g protein)	Camel milk	Cow milk
Alanine	3.1-3.4	3.5-4.8
Arginine	3.2-4.6	2.9-4.2
Aspartic acid	6.2-7.7	6.2-7.8
Glutamic acid	15.4-23.5	15.8-23.2
Glycine	0.6-6.6	0.8-2.1
Histidine	2.5	3.0
Leucine	18-21	8.1-17.0
Lysine	7.6	8.1
Methionine	3.5	3.2
Phenyl alanine	5.7	5.4
Proline	13.3	10.1-11.8
Serine	5.9	6.6
Threonine	6.3	4.3
Tyrosine	5.8	5.8
Valine	7.4	7.5

proved effective supplementation in the management of type 1 diabetes, as there was significant reduction in fasting blood sugar along with betterment in BMI. However, there was no change in lipid profile. (11).

Similar results were found in controlled cross over study. Randomly selected type 1 diabetic patients were divided into 2 groups. Group 1 (N=12) received usual care i.e. standardized diet, standardized exercise regimen and insulin for 3 months. Then camel milk (500 ml) was added for next 3 months. Patients of group 2 (N=12) received camel milk (500 ml) and usual care for first 3 months and only usual care in next 3 months. Frequent blood glucose monitoring was done to keep euglycemic status by titrating the dose of insulin. Analysis of HbA_1c, lipid profile, insulin and C-peptide was done in the beginning, at the end of third and sixth month. In group 1 patients the requirement of insulin was 40.83 ± 7.12 at the beginning, 41.67 ± 5.49 after 3 months and it reduced to 26.83 ± 8.44, ($\rho<0.05$) after camel milk supplementation. In group 2 dose of insulin increased from 30.00 ± 13.01 to 40.57 ± 15.20 when camel milk was withdrawn. Improvement in mean blood glucose (7.11 ± 0.32 to 5.96 ± 0.31, $\rho<0.05$) was observed in group 1. In the same group HbA_1c reduced from 9.48 ± 2.17 to 8.19 ± 1.84 and in group 2 HbA_1c decreased from 9.59 ± 1.62 to 8.02 ± 1.17. Statistically significant improvement was seen in D.Q.L. score. It is concluded that moderate intake of camel milk will reduce the insulin requirement with better glycemic control and diabetes quality of life without affecting lipid profile. (12).

In another, 52 weeks randomized controlled study, Group 1 (n=12) received usual care and Group 2 (n=12) received 500ml camel milk in addition to usual care for 1 year. After 1 year of treatment there was significant increase in body mass index (17.4 to 19.7±2.97 kg/m^2, $p<0.001$), improvement in fasting blood sugar (119±19 to 95.42±15.70 mg/dl, $p<0.003$) and HbA1c (7.8±1.38 to 6±0.96%, $p<0.001$). In group 2 there was a significant reduction in the mean doses. No significant treatment emerged adverse events were reported in either group. (8).

There is a traditional belief in the Middle East that regular consumption of camel milk may aid in prevention and control of diabetes. The aim of this work was to evaluate the efficacy of camel milk as an adjuvant therapy in young type 1 diabetics. This 16-week randomized study enrolled 54 type 1 diabetic patients (average age 20 years). Subjects were randomly divided into two groups of 27 patients: one received usual management (diet, exercise, and insulin), whereas the other received 500 ml of camel milk daily in addition to standard management. A control group of 10 healthy subjects was also assessed. Hemoglobin A1c (HbA1c), human C-peptide, lipid profile, serum insulin, anti-insulin antibodies, creatinine clearance, albumin in 24-hour urine, body mass index, and Diabetes Quality of Life score were evaluated at baseline and at 4 and 16 weeks:. These parameters were significantly different between the usual-management group versus the camel milk group after 16 weeks: fasting blood sugar (227.2 +/- 17.7 vs. 98.9 +/- 16.2 mg/dL), HbA1c (9.59 +/- 2.05[%] vs. 7.16 +/- 1.84[%]), serum anti-insulin antibodies (26.20 +/- 7.69 vs. 20.92 +/- 5.45 microU/mL), urinary albumin excretion (25.17 +/- 5.43 vs. 14.54 +/- 5.62 mg/dL/24 hours), daily insulin dose (48.1 +/- 6.95 vs. 23 +/- 4.05 units), and body mass index (18.43 +/- 3.59 vs. 24.3 +/- 2.95 kg/m(2)).These results suggest that, as an adjunct to standard management, daily ingestion of camel milk can aid metabolic control in young type 1 diabetics, at least in part by boosting endogenous insulin secretion. (36).

Effect of camel milk on insulin dose

Along with significant decrease in mean fasting blood glucose levels, a significant reduction in the doses of insulin requirement was also observed in different studies. There was a significant reduction in the mean doses of insulin (41.16±10.32 to 30±12.6 u, $p<0.002$) in patients receiving camel milk.(9) The dose of insulin reduced from 41.67±5.49 to 26.33±8.44 ($p<0.05$) when camel milk was added. Similar benefits were observed in group 2 when patients were taking camel milk (41.67±15.65 to 30.00±13.01) but when camel milk was withdrawn there was more requirement of insulin (30.00±13.01 to 40.57±15.20)(11). In further study a significant reduction in the mean doses of insulin (32±12 to 17.83±12.40, $p<0.005$) was observed again.(12)

Camel milk, adjunct to insulin therapy improves glycemic control and lowers insulin requirement without risk of hypoglycemia in patients with type 1 diabetes. The important observation of the randomized controlled trial was a significant reduction in insulin requirement (46.15%) at the end of two years in patients taking camel milk, in comparison to control group. Amongst the twelve subjects in camel milk consuming group, each patient had significant response in reduction in insulin requirement but the remarkable observation was gradual reduction upto zero in three subjects. These three subjects reached to this level on 12th, 18th and 21st month of the study and returned to this 'no insulin requirement status' upto the end of study with some intermittent deviations. Two out of these three subjects maintained this zero level continuously from 18th and 21st month till the end of study.Out of 12 subjects receiving camel milk, insulin requirements in 3 subjects was reduced to zero. (4). (fig.1).

Effect of camel milk on diabetes quality of life score

There was stastically significant improvement in diabetes quality of life score when camel milk was added along with usual care. In group 1 patient there was improvement in satisfaction score (26.25±1.96 to 22.25±4.56, $\rho<0.05$), impact score (32.58±2.64 to 26.5±3.73, $\rho<0.05$) and worry score (14±1.04 to 11.33±1.83, $\rho<0.05$). Similar positive response in diabetes quality of life score was seen in group 2 when patients were on camel milk but when it was withdrawn there was deterioration in satisfaction score (27.58±2.19 to 30.00±2.52, $p<0.05$) without affecting the impact score and worry score (12).

Effect of camel milk on lipid profile, plasma insulin and c-peptide

Fasting plasma insulin and c-peptide levels did not reveal any significant change in camel milk consumer as well as non consumer group and similar observation was made with levels of lipid profile (12).In another study C-peptide levels were markedly higher in the camel milk group (0.28 +/- 0.6 vs. 2.30 +/- 0.51 pmol/mL).(36).

Effect on β cell function

To understand how the camel milk is helping in type 1 diabetes and the effect of camel milk on residual β-cell function in recent onset type 1 diabetes a study was carried out and concluded that the mean basal C-peptide gradually increased in camel milk group from 0.14 ± 0.10 to 0.16 ± 0.10. The improvement in β-cell may be due to: a) Euglycemia possibly reduces -cell work, leading to β-cell rest, and thereby preserving β-cell function. b) Tolerance induction in the body due to high concentration of circulating insulin (antigen) leading to preservation of β-cell function. c) Camel milk immunoglobulins are of relatively smaller size and weight due to only Y shaped main chain which might offer an interplay with host cell protein thereby leading to an induction or activation of regulatory cells and finally leading to a downward regulation of immune system and β-cell salvage. d) Protective effect of β-cell function may be due to presence of half – cystine, lactoferrin or insulin like factor in camel milk. (7) (fig.2).

Beneficial effect of camel milk in diabetic nephropathy

A study was performed to observe the role of camel milk in controlling microalbuminuria level of type-1 diabetic patients. . Twenty four patients were randomly recruited and then these patients were given camel milk in addition with usual care for six months. Urine microalbumin was tested by micral test. It was found that after adding camel milk to the usual regimen there was improvement in microalbuminuria (119.48±1.68 to 22.52±2.68;p0.001). It may be due to good glycemic control or due to direct effect of camel milk. (5).

EPIDEMIOLOGICAL STUDIES IN CAMEL MILK CONSUMING COMMUNITY

Raica is a tribal community scattered over the area of Thar desert which not only habitually cares for the camel but also consumes its milk having several health benefits. The objective of the study was to focus on the rural Raica community of north-west Rajasthan and to study the cultural, genetic and environmental differences which contribute to the low prevalence of diabetes in this population. A cross-sectional survey using stratified sampling of a representative Raica community subjects consuming camel milk, and Raica community and non-Raica community subjects not consuming camel milk was carried out.

The fasting as well as post-glucose load glucose levels were significantly lower in Raica community subjects as compared to the non-Raica community subjects in the same region (fasting 89.0±15.0 vs. 96.2±20.3 mg/dl; post-glucose 120.2±17.5 vs. 131.2±30.2 mg/dl; $p<0.001$). In camel-milk consuming Raica subjects the age-adjusted prevalence of diabetes (0.0%), impaired fasting glucose (3.2%), and impaired glucose tolerance (8.6%) was significantly lower than other-milk consuming Raica subjects (4.6%, 7.8%, and 20.6%) and non-Raica subjects (7.5%, 13.4% and 15.1%) respectively ($p<0.01$). It was concluded from this survey that prevalence of impaired glucose tolerance as well as diabetes is low in the rural Raica community subjects of north-west Rajasthan. The prevalence of both is the lowest in camel-milk consuming Raica community subjects. (9).

Further a cross sectional study was conducted to describe the prevalence and clinical factors associated with impaired fasting glucose (IFG), impaired glucose tolerance (IGT) and diabetes mellitus (DM) among adults (20 years) in large population group. 2099 participants from different villages of north-west Rajasthan were selected using stratified sampling of a representative Raica and non-Raica Community, consuming or not consuming camel milk. Demographic, clinical, anthropometric parameters were obtained and oral glucose tolerance tests were performed in all individuals to diagnose IFG, IGT and DM. In this study, the prevalence of diabetes in Raica community consuming camel milk (RCCM, n = 501) was 0%; Raica community not consuming camel milk (RCNCM, n = 554) was 0.7%; non-Raica community consuming milk (NRCCM, n = 515) was 0.4% and non-Raica community not consuming camel milk (NRCNCM, n = 529) was 5.5%. Stepwise logistic regression analysis showed that consumption of

Table 3. Multivariate Logistic Regression Analysis

Parameters	Odds Ratio	95% CI		P value
		Lower	Upper	
Age	1.017	0.985	1.050	0.304
BMI	0.914	0.823	1.013	0.088
Socio economic status	0.634	0.273	1.471	0.289
Life style	1.788	1.038	3.079	0.036
Systolic BP	0.979	0.952	1.006	0.121
Diastolic BP	1.005	0.952	1.062	0.853
Camel milk	12.135	3.634	40.526	0.000
Community	6.537	2.218	19.268	0.001

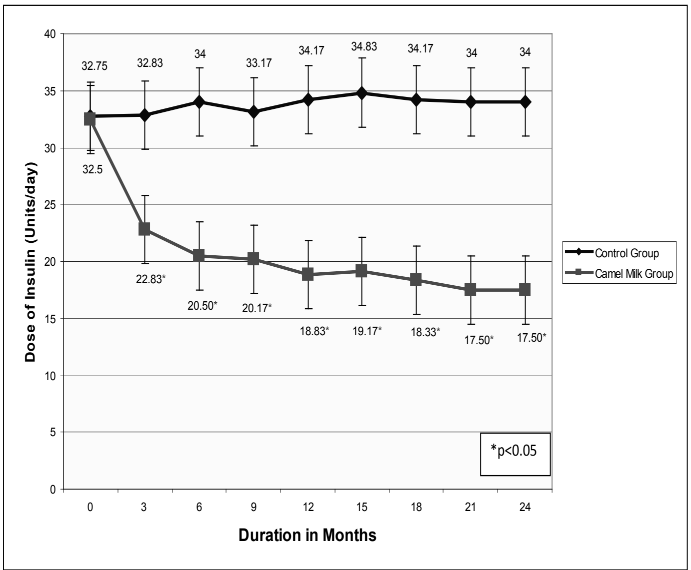

Figure 1. Mean dose of insulin of control and camel milk groups.
Source: R P Agrawal, S Jain, S Shah, A Chopra and V Agarwal "Effect of camel milk on glycemic control and insulin requirement in patients with type 1 diabetes: 2-years randomized controlled trial" European Journal of Clinical Nutrition, 2011; 65: 1048-1052.

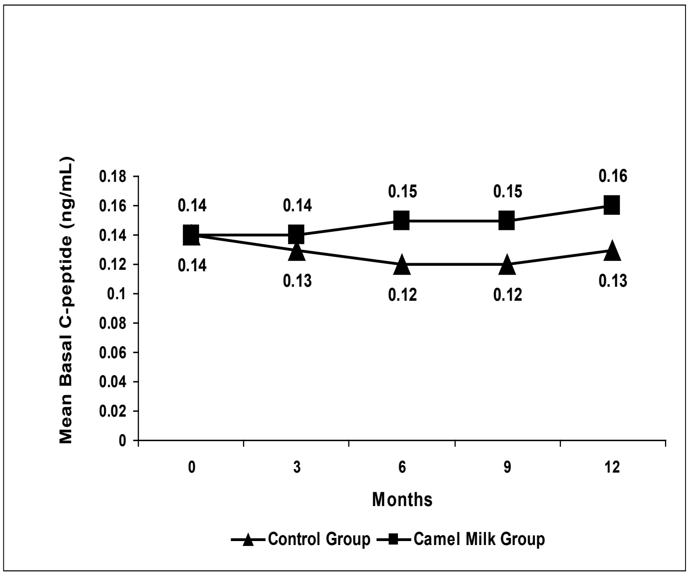

Figure 2. Comparison of mean basal C-peptide level in both groups
Source: R.P.Agrawal, Sanjay Saran, Poornima Sharma, R.P.Gupta, D.K.Kochar, M.S.Sahani "Effect of camel milk on residual b-cell function in recent onset type 1 diabetes" Diabetes Research and Clinical Practice, Volume 77, 2007, 494-495.

camel milk was statistically highly significant as protective factor for diabetes. Multiple logistic regression analysis revealed that camel milk consumption and community factor were associated with decreased prevalence of diabetes. It was concluded that camel milk consumption and lifestyle have definite influence on prevalence of diabetes. Hence, adopting such life pattern may play protective role in preventing diabetes to some extent. (3).

Multiple logistic regression analysis revealed that camel milk consumption and community factor were associated with decreased prevalence of diabetes.

STUDIES IN EXPERIMENTAL ANIMALS

A controlled study of the oral hypoglycemic activity of camel milk was investigated in rats. Thirty-two white albino rats of approximately same age group having body weight ~150 g were acclimatized under laboratory conditions for a week by keeping them on diet of wheat dalia (wheat crushed into small pieces) and water ad lib., their fasting blood sugar level, by depriving food overnight but allowing free access to water, was estimated. The rats were divided into four groups (Gr.1, Gr.2, Gr.3 and Gr.4) of 8 rats each. Hyperglycemia was induced in rats of Gr.1, Gr.2 and Gr.3 by intraperitoneal administration of streptozotocin (50 mg/kg b.wt), whereas rats in Gr.4 were kept as untreated controls. Fasting blood sugar levels of all these animals were estimated after 3 days of treatment. These animals besides normal diet of wheat dalia were offered raw camel milk (Gr.1), raw cattle milk (Gr.2), water (Gr.3) and normal diet (Gr.4). Rats of Gr.1 and Gr.2 were given 250 ml of milk daily through watering bottle, whereas animals in Gr.3 and Gr.4 were given tap water. The serum sugar levels of these rats were estimated at weekly interval for 3 consecutive weeks. Blood samples were drawn from cardiac puncture using tuberculin syringe from overnight fasted rats, serum samples were harvested and glucose level was determined spectrophotometrically employing glucose oxidase method.

Initial mean serum level of treated rats was 191.33±7.46 mg/dl whereas in sugar untreated control it was 80.6±12.07 mg/dl. In Gr.1 after 1st, 2nd and 3rd week of trial mean blood sugar level was 98.0±3.37, 89.0±5.23 and 86.25±12.77 mg/dl, in Gr.2 it was 158.4±11.34, 132.8±23.49 and

110.0±9.97 mg/dl, whereas in Gr.3 it was 203.6±10.11, 132.8±23.49 and 124.5±24.21 mg/dl respectively. Every time mean blood sugar level in untreated group was within the normal range (70-90 mg/dl). During 3 weeks of trial there was a significant decrease in the mean blood sugar level of all the treated groups getting raw camel milk. The overall mean of three weeks trial showed a significant decrease in mean blood sugar level of Gr.1 rats getting camel milk, as compared to Gr.2 rats getting raw cattle milk. (6).

Another study was conducted to evaluate the effect of camel milk in alloxan-induced diabetic dogs and to follow this effect at three doses of milk. Firstly, three groups of dogs were used: two groups composed each of four diabetic dogs and receiving raw camel milk (treatment 1) or cow milk (treatment 2), and four healthy dogs getting raw camel milk (treatment 3) were used as control. Each animal was treated with 500 ml of milk daily. Secondly, the effects of three different amounts of camel milk: 100 ml, 250 ml and 500 ml to treat the diabetic dogs were compared. After week 3, the dogs treated with camel milk showed a statistically significant decrease in blood glucose (from 10.88 +/- 0.55 to 6.22 +/- 0.5 mmol/l) and total protein concentrations (from 78.16 +/- 2.61 g/l to 63.63 +/- 4.43 g/l). For cholesterol levels, there was a decrease from week 2 (from 6.17 +/- 0.5 mmol/l to 4.79 +/- 0.5 mmol/l). There were no significant difference in blood glucose, cholesterol or total protein concentrations in dogs drinking 250 and 500 ml of camel milk. The dogs treated with 100 ml of camel milk did not show any significant decrease in blood glucose levels, and cholesterol and total protein concentrations. The investigation was not limited to the improvement in glycemic balance, lipids and proteins control in diabetic dogs getting camel milk, but we also noted a stability of this state after the dogs stopped to drink milk. This effect depended on the quantity of camel milk used to treat diabetic dogs. (43).

POSSIBLE MECHANISMS INVOLVED

The exact cause of hypoglycemic effect of camel milk is not known. It is possibly due to insulin like activity, regulatory and immuno modulatory function of β cells (32). Agamy found good amount of lysozyme, lactoferrin, lactoperoxidase, immunoglobulin G and secretory immunoglobulin A in camel milk (21). The lack of coagulum formation of camel milk may also be helpful in taking the insulin present in it unchanged to intestine where it can be absorbed even if some amount is destroyed in the passage. Beg has found that amino acid sequence of some of the camel milk protein is rich in half cystine, which has superficial similarity with insulin family of peptides (13). Low prevalence of diabetes in camel breeder community (Raica) paves path to novel approaches lying behind the glycemic control attributed to camel milk.The differences in the prevalence may also be attributed to other variables like BMI, lifestyle, socioeconomic status, dietary habits, but multiple logistic regression, applied in a study carried out by Agrawal et al had shown that camel milk consumption had the highest significant protective value against development of diabetes mellitus. Since camel prefer grazing on natural vegetation mostly desert bushes, salty plants and herbs including neem which may allow some of the phyto-chemicals to be secreted in camel milk which might be having antidiabetic action.(3).

SUMMARY AND CONCLUSION

Camel milk, has emerged as a potent therapeutic alternative which can help in reducing insulin doses. Primary treatment of type-1 diabetes mellitus is insulin replacement. Although, conventional injectable insulin therapy meets this goal, it is associated with several therapeutic disadvantages, such as hyperinsulinaemia, pain and inconvenience. Many attempts have been made to find alternative methods of insulin delivery via non-invasive routes (39,26,17). Amongst the alternative routes available for insulin delivery, oral administration is the most preferable as it offers significant advantages in terms of therapeutic efficacy and patient acceptability. Since orally delivered insulin undergoes a hepatic pass before entering the circulation, it has the potential to mimic the effects of pancreas-secreted insulin in terms of inhibition of hepatic gluconeogenesis (31,18). Camel milk is one such alternative as one of its proteins has many characteristics similar to insulin (2) and it does not form coagulum in acidic environment, safeguarding the viability of its components and making it available for absorption in intestine.

A number of studies have proved that camel milk as an adjunct to insulin therapy, appears to be safe and efficacious in improving long-term glycaemic control and helps in reduction of insulin requirement in type 1 diabetic patients. Till now, it is being thought that amount of insulin present in milk is playing vital role. Its therapeutic efficacy may be due to lack of coagulum formation in the acidic media. These studies and field survey clearly reveal that there appears to be a scientific justification for drinking camel milk by certain diabetic patients. Lack of any study against favorable relationship between camel milk and diabetes emphasizes this justification.

Camel milk is considered as the white gold of the desert. But there is still no cultural tradition of drinking camel milk in India, except among the camel breeders, this approach needs to be amended. Camel milk has not only nutritional value; it also resembles a wonder drug: containing enzymes with anti-bacterial and anti-viral properties, it helps to fight diseases of many kinds. This is why it has not only been used traditionally to treat tuberculosis and typhoid, but according to scientists, may also have a positive effect on patients with HIV/AIDS, cancer and Alzheimer's disease. Furthermore, no allergies against camel milk are known and even lactose intolerant people can drink it. Maybe most significantly, camel milk contains insulin and has been shown to reduce blood sugar levels in diabetic patients – which is very pertinent, considering that India faces a diabetes crisis as people eat more sugar-rich food and drinks. Camel milk is already marketed as a health food and beauty product in the Gulf and several African countries and the global market potential for camel milk could be billions of dollars, according to estimates by the Food and Agriculture Organisation (FAO) of the United Nations.

Hence, food industry could design and construct functional foods with probiotics. These food products could be positioned between conventional foods and medicines, with their uses targeting semi healthy state of the body as a preventive measure against disease. This concept is consistent with the historic belief that natural substances play an important role in prevention and treatment of diseases.

REFERENCES

1. Abeiderrahmane, N.M. and Reed, D.W. Pasteurizing camel's milk and making camel's cheese in Mauritania. Spirit of enterprise: the-1993 Rolex Awards, Buri International; Bern; Switzerland, 1993, 72-75.

2. Abu-Lehia, I.H.I.S., Al-Mohizea and M.El-Behary. Studies on the production of ice cream from camel milk products. *Aust. J. Dairy Technol.* 1989, **44:** 31-34.

3. Agrawal, R.P., Budania, S., Sharma, P., Gupta, R., Kochar, D.K., Panwar, R.B. and Sahani, M.S. Zero prevalence of diabetes in camel milk consuming Raica community of north-west Rajasthan, *India. Diab. Res. Clin. Pract.* 2006, **76:** 290-296.

4. Agrawal, R.P., Jain, S., Shah, S., Chopra, A. and Agarwal, V. Effect of camel milk on glycemic control and insulin requirement in patients with type 1 diabetes: 2-years randomized controlled trial. *Euro. Jr of Clin Nutri.* 2011, **65:**1048-1052.

5. Agrawal, R.P., Dogra, R., Mohta, N., Tiwari, R., Singhal , S. and Sultania, S. Beneficial effect of camel milk in diabetic nephropathy. *Acta Bio.* 2009, **80:**131-134.

6. Agrawal, R.P., Sahani, M.S., Tuteja, F.C., Ghorui, S.K., Sena, D.S., Gupta, R. and Kochar, D.K. Hypoglycemic activity of camel milk in straptozotocin induced hyperglycemia in rats. *Int. J. Diab. Dev. Countries.* 2005, **25:** 75-79.

7. Agrawal, R.P., Saran, S., Sharma, P., Gupta R.P., Kochar, D.K. and Sahani, M.S. Effect of camel milk on residual b-cell function in recent onset type 1 diabetes. *Diab Res and Clin Prac.* 2007, **77:** 494-495.

8. Agrawal, R.P., Sharma, S., Beniwal, R., Kochar, D.K., Tuteja, F.C., Ghorui, S.K. and Sahani, M.S. Camel milk as an adjunct to insulin therapy improves long-term glycemic control and reduction in doses of insulin in patients with type-1 diabetes A 1 year randomized controlled trial. *Diab Res Clin Pract.* 2005, **68(2):**176-7.

9. Agrawal, R.P., Singh, G., Nayak, K.C., Kochar D.K., Sharma, R.C., Beniwal, R., Rastogi, P. and Gupta, R. Prevalence of Diabetes in Camel Milk Consuming 'RAICA' Rural Community of North West Rajasthan. *Int. J. Diab. Dev. Countries.* 2004, **24:** 109-114.

10. Agrawal, R.P., Swami, S.C., Beniwal, R., Kochar, D.K. and Kothari, R.P. Effect of Camel Milk on Glycemic Control, Risk Factors and Diabetes Quality of Life in Type-1 Diabetes: A Randomised Prospective Controlled Study. *Int. J. of Diab. Dev. Countries.* 2002, **22:** 70-74.

11. Agrawal, R.P., Swami, S.C., Beniwal, R., Kochar, D.K., Sahani, M.S., Tueja, F.C. and Ghorui, S.K. Effect of camel milk on glycemic control risk factors and diabetes quality of life in type-1 diabetes: a randomised prospective controlled study. *Jr of camel pract and Res.* 2003, **10:**45-50.

12. Agrawal, R.P., Swami, S.C., Beniwal, R., Sahani, M.S., Tuteja, F.C. and Ghorui, S.K. Effect of camel milk on glycemic control lipid profile and diabetes quality of life in type-1 diabetes: a randomised prospective controlled cross over study. *Indian Jr of Animal Sci.* 2003, **73(10):** 1105-1110.

13. Beg, O.U., Von Bahr, Lindrom, H., Zaidid, Z.H and Jornvall, H. A camel milk protein rich in half cystine. Primary structure assessment of variations, internal repeat patterns and relationship with neurophysin and other active polypeptides. *Euro Jr of Biochem.* 1986, **15:**195-201.

14. Belokobylenko, V.T. and Mausaev. Machine milking of camels without suckled calves (in Russian). *Sbornik Nauchnykh trudov.* 1982, 116-123.

15. Belokobylenko, V.T. Zootechnical background to the production of shubat at modern farms (in Russian). *Sbornik Nauchnykh trudov.* 1982, 106-112.

16. Bozzi, L. and Triulzi, G.A. Osservazioni sugli animali domestici allevati in Somalia. *Rivista di Agri. Subtrop. e Trop.* 1953, **47:** 266-294.

17. Cefalu, W.T. Concept, strategies and feasibility of non-invasive insulin delivery. *Diab Care.* 2004, **27:** 239-246.

18. Clement, S., Still, G., Kosutic, G. and McAllister, R.G. Oral insulin product hexyl-insulin monoconjugate 2 (HIM2) in type 1 diabetes mellitus: the glucose stabilization effects of HIM2. *Diab Tech and Therap.* 2002, **4:** 459-466.

19. Dahlborn, K.S., Benlamlih, C., Wallsten, J. and Hossaini-Hillai. Effects of food deprivation on fluid balance and glucose regulation in pregnant and lactating camels in W.R. Allen, A.J. Higgins, I.G. Mayhew, D.H. Snow and J.F. Wade (eds.) Proc. 1st Int. Camel Conf. R & W. Publications Ltd, Newmarker; UK. 1992, 275-277.

20. Dzhumagulov, I.K. Hybridization in camel breeding (in Russian). *Zhivotnovodstvo.* 1983, **9:** 46-47.

21. El-Agamy, E.I., Ruppanner, R., Ismail, A., Champagne, C.P.and Assaf, R. Antibacterial and antiviral activity of camel milk protective proteins. *J Dairy Res.* 1992, **59(2):**169-75.

22. Elamin, F.M. and Wilcox, C.J. Milk composition of Majaheim camels. *J. Dairy Sci.* 1992, **75:** 3155-3157.

23. Farah, Z. Composition and characteristics of camel milk. *J.Dairy Res.* 1993, **60:** 603-626.

24. Farah, Streiff, Z.T. and Bachmann, M.R. Manufacture and characterization of camel milk butter. *Milchwissenschaft.* 1986, **44:** 412-414.

25. Gorban, Ali, M.S. and Izzeldin Omar, M. Mineral Content of Camel Milk and Colostrums, pp.1-3. *J. Dairy Res.* 1997, **64:** 471-474.

26. Gordberg, M. and Gomez-Orellana, I. Challenges for the oral delivery of macromolecules. *Nature Rev Drug Dis.* 2003, **4:** 289-295.

27. Hamers-Casterman, C., Atarhouch, T., Muyldermans, S., Robinson, G., Hamers, C., Songa, E.B., Bendahman, N. and Hamers, R. Naturally occurring antibodies devoid of light chains. *Nature.* 1993, **3:**446-8.

28. Knoess, K.H. Milk production of the dromedary. In: Camels. IFS Symposium, Sudan. 1979, 201-214.

29. Knoess, K.H. Milk production potential of the dromedary. *Pakistan Vet.* J. 1982, **2:** 91-98.

30. Knoess, K.H., Makhudum, A.J., Rafiq, M. and Hafez, M. Milk production potential of the dromedary, with special reference to the province of Punjab, Pakistan. *World anim. Rev.* 1986, **57:** 11-21.

31. Lewis, G.F., Zinman, B., Groenewound, Y., Vranic, M. and Giacca, A. Hepatic glucose production is regulated both by direct hepatic and extrahepatic effects of insulin in humans. *Diabetes.* 1996, **45:** 454-462.

32. Lutz, B. Insulin and antidiabetic activity of camel milk. *Jr of camel res and prac.* 2002, **9:** 43-45.

33. Mares, R.G. Animal husbandry animal industry and animal diseases in the Somaliland protectoreate, part II. *Br. Vet. J.* 1954, **110:** 470-481.

34. Mehaia, M.A. Fresh soft white cheese (Domiati-type) from camel milk: composition, yield and sensory evaluation. *J.Dairy Sci.* 1993, **76:** 2845-2855.

35. Mehaia, M.A. Vitamin C and riboflavin content in camels milk: effects of heart treatments. *Food Chem.* 1994, **50:** 153-155.

36. Mohamad, R.H., Zekry, Z.K., Al-Mehdar, H.A., Salama, O., El-Shaieb, S.E., El-Basmy, A.A., Al-said, M.G. and Sharawy, S.M. Camel milk as an adjuvant therapy for the treatment of type 1 diabetes: verification of a traditional ethnomedical practice. *J Med Food.* 2009, **12(2):**461-5.

37. Mohamed, M.A. Camel milk: chemical composition, characterization of casein and preliminary trial of cheese-making properties. Ph.D. thesis, Swedish Univ. of Agricult. Sciences, Uppsala. 1990.

38. Musaev, Z.M. Milk production of Khazakh bactrian camels at mechanized farms (in Russian) *Sbornik Nauchnykh trudov.* 1982, 123-127.

39. Owens, D.R. New horizons-alternative routes for insulin therapy. Nature Rev Drug Discov. 2002, **1:** 529-540.

40. Rao, M.B.R., Gupta, C. and Dastur, N.N. Camel's milk and milk products. *Ind. J.Dairy Sci.* 1970, **23:** 71-78.

41. Rogers, A. Memories of Jahangir. Allantic Publishers and Distributor, New Delhi. 1986, 315.

42. Sahani, M.S., Mal, G., Kumar, R., Saina, D.S. and Jain, B.K. Annual Report on Camel milk and its role in tuberculosis. NRCC, Bikaner. 1989, 7-8.

43. Sboui, A., Khorchani, T., Djegham, M., Agrebi, A., Elhatmi, H. and Belhadj, O. Anti-diabetic effect of camel milk in alloxan-induced diabetic dogs: a dose-response experiment. *J Anim Physiol Anim Nutr (Berl)*. 2010, **1:**540-6.
44. Schwartz, H.J. and Walsh, M.G.H. The productive potential of the camel in H.J. Schwartz and M. Dioli (eds.) The one humped camel in eastern Africa Verlag, Weikersheim, Germany. 1992.
45. Sharmanov, T. Sh., Kadyrova, R. Kh. and Salkhanova B.A. Treatment of peptic or duodenal ulcer patients with diets containing mares `or camel` milk (in Russian). *Voprosy Pitaniya.* 1981, **3:** 10-14.
46. Sharmanov, T.Sh., Zhangabylov A.K. and Zhaksylykova R.D. Mechanism of remedial action of whole mares `and camels` milk in chronic hepatitis (in Russian). *Voprosy Pitaniya.* 1982, **1:** 17-23.
47. Shehadeh, N., Gelertner, L., Blazer, S., Perlman, R., Solovachik, L. and Etzioni, A. Importance of insulin content in infant diet: suggestion for a new infant formula. *Acta Paediatr.* 2001, **90(1)**:93-5.
48. Singh, R. Annual Report of National Research Centre on Camel, Bikaner, India. 2001.
49. Urazakov, N.U. and Bainazarov, Sh. `Tushchibek` - the first clinic in history for the treatment of pulmonary tuberculosis with cultured camels milk (in Russian). *Probl. Tuberk.* 1974, **2:** 89-90.
50. Wangoh, J. What steps towards camel milk technology? *Int Jr of Anim Sci.* 1993, **8:**9-11.
51. Wernery, U., Bobby Johnson and Tawfiq Ishmail, W. Insulin content in raw dromedary milk and serum measured over one lactation period. *J. Camel Prac. and Res.*, 2006, **13:** 89-90.
52. Wernery, U., Ali, M. Kinne, J. Abraham, A.A. and Warnery, R. Copper deficiency: A predisposing factor to septicaemia in dromedary calves. *J. Camel Prac. and Res.* 2002, **9(1)**: 59-66.
53. Willium, F Ganong, Review of Medical Physiology. 1999, **19:** 431.
54. Wilson, R.T. The Camel, Longman, London and New York. 1984.
55. Yagil, R. The desert camel: comparative physiology. Vol 5. Co., Animal Nutri. Basel, Karger. 1985.
56. Yagil, R. and Etzion, Z. Effects of drought condition on the quality of camel milk. *J. Dairy Res.* 1980, **47:** 159-166.