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Churning efficiency and microbial quality of butter made from camel milk alone and blending it with goat milk

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ABSTRACT

In this study, the churning efficiency of milk sample for buttermaking from camel milk by blending it with goat milk and microbiological quality of butter made at different blending levels were assessed. The experiment was laid out in completely randomized design with five treatments: T1 (100% camel milk), T2 (75% camel and 25% goat milk), T3 (50% camel and 50% goat milk), T4 (25% camel and 75% goat milk) and T5 (100% goat milk). The churning efficiency and microbiological quality of the milk and butter samples were analyzed following standard procedures. The fermentation time (11.33 days), churning time (121.7 min) and churning temperature (28°C) of T1 were significantly ($P < 0.001$) higher than the other milk samples. T1 had significantly ($P < 0.001$) lower churning pH (4.13) and butter yield (49.3 g/L) than the other samples. T3 and T4 had significantly ($P < 0.001$) higher butter yield than the other milk samples. The fermentation time, churning time and churning temperature of T5 were significantly ($P < 0.001$) lower than the rest and T5 required significantly ($P < 0.001$) higher churning pH than the other milk samples. The coliform count (CC), enterobacteriaceae count (EBC), lipolytic bacteria count (LBC) and yeast and mould count (YMC) of T1 was significantly ($P < 0.001$) higher than the other butter samples. The CC, EC and total bacteria count (TBC) of T5 was significantly ($P < 0.001$) higher than T2, T3 and T4 and it had significantly ($P < 0.001$) lower TBC than the others. The results showed that blending camel milk with goat milk improved churning efficiency and microbial quality of butter made from camel milk at different blending levels. Although butter can be made from pure camel milk, it took longer churning time and fermentation time. Thus, research is needed in order to reduce the churning time, improve the yield of butter and microbial quality made from pure and blended camel milk by manipulating the operating parameters viz., pH of the milk, churning temperature, method of churning and volume of milk in the churn.

Keywords: Blending, butter, churning efficiency, microbial quality.

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INTRODUCTION

Ethiopia possesses over 2.4 million dromedary camels that stand the country third in Africa in camel population (FAO, 2010). Camels are kept, among other things, mainly for milk production in the pastoral areas. They produce milk for quite longer period even during dry periods compared to cattle (Kurtu, 2003). The majority of camels in the country are found in the drier areas of the Eastern part of the country. Dromedary camels are naturally browsers, thrive on sparse pasture and produce milk where other domesticated animals would virtually starve (Zubeir et al., 2010). This characteristic makes the lactating camel a very valuable animal for the survival of the camel herders and their family in this harsh environment. The annual camel milk production in Ethiopia is estimated 75,000 tonnes (Felleke, 2003). Camel milk is an important component of human diet in many parts of the world. The present knowledge about the milk production potential of camels (*Camelus dromedarius*) is very limited. However, a healthy camel on good feed can produce 2000 L of milk per lactation

period (Knoess et al., 2008). Most of the camel milk is drunk fresh or when it is slightly sour in pastoral areas of the country.

Camel milk is not churnable by the traditional methods owing to the chemical nature of the milk. Therefore, milk produced from camels is primarily used for direct consumption by the pastoralists. Pastoralists claim that it is difficult to churn camel milk to make butter (Yagil, 1982) and further stated that butter from camel milk cannot be obtained so easily using the traditional churning methods because camel milk shows little tendency to cream up and the fat in camel milk is firmly bound to the protein (Rao et al., 2011). Although it is difficult to make butter from camel milk, reports revealed that butter can be made from camel milk by churning fresh or soured camel milk at 24 to 25°C (Farah et al., 2007). In the Algerian Sahara, there is a popular butter made from camel milk and is called *Shmen or Semma* (Mourad and Nour-Eddine, 2006). In this region, fresh camel milk butter is difficult to preserve because it usually contains many impurities (sand, hair, etc.) and rapidly becomes rancid. The Touaregs (nomad tribe of Sahara) improve the shelf life of camel milk butter by transforming it into clarified butter oil (*Shmen*). This product has been playing a major role in the diet of Touareg communities in the Sahara, and today there is a special demand for this product among consumers.

In pastoral areas, large amounts of camel milk are produced but buttermaking from camel milk is difficult due to the inherent characteristics of the milk. In addition to camel milk, milk from small ruminants particularly goats is also available in pastoral areas. Thus, the possibility exists to make butter from camel milk by blending it with goat milk. Hence, knowledge of the factors that influence buttermaking and the possibilities of churning camel milk to make butter are very important aspects of camel milk processing for enhancing the product and value addition of camel milk that will subsequently enrich the diets and income of the pastoralists. Fresh milk is easily perishable if it is not consumed immediately. So when surplus amount of milk is produced, it should be processed into different products like butter, soured milk and cheese. Butter has long shelf life as compared to fresh milk, especially when heated to higher temperature (100 to 120°C) for 30 min it can stay for several months without spoilage (Lejko et al., 2009).

The initial flora of the raw milk, the processing conditions, and post-processing handling influences the microbiological quality of milk and dairy products. Undesirable microbes that can cause spoilage of dairy products include Gram-negative psychrotrophs, coliforms, lactic acid bacteria, yeasts and moulds. In addition, various bacteria of public health concern such as *Salmonella* spp, *Listeria monocytogenes, Campylobacter jejuni, Yersinia enterocolitica,* pathogenic strains of *Escherichia coil* and enterotoxigenic strains of *Staphylococcus aureus* may also be found in milk and dairy products (Tatini and Kauppi, 2002). For this reason, increased emphasis has been given to the microbiological examination of milk and milk products. Microbiological analyses are critical for the assessment of quality and safety of dairy products and for conformation with standards and specifications set by regulatory agencies. In the scientific literature, there is a relative scarcity of data pertaining to the levels of microorganisms and pathogens in camel milk and camel milk products. Camel milk butter is believed to have some medicinal properties and laxative properties for gastrointestinal discomfort in different parts of the world (Rao et al., 2011). Camel milk butter is also used in the preparation of nutritious and medical soups. The byproduct of butter, that is, buttermilk, is used as a functional ingredient in many food products such as salad dressings, pasta sauces, chocolate, cheese seasonings, ice cream mixes and yoghurt (Fox et al., 2000). Therefore, buttermaking from camel milk and analysis of its quality has multi dimensional advantages. It is against this background and justification that this research work was conducted with the following objectives:

1. To evaluate the churning efficiency of making butter from camel milk by blending it with goat milk.
2. To evaluate the microbiological quality of butter obtained from camel milk at different blending levels.

MATERIALS AND METHODS

Description of the study area

Goat milk samples for buttermaking were collected from pastoralists in Somali Regional State specifically from Jigjiga woreda Hodle Kebele. Jigjiga Woreda is one of the six administrative woredas of the Jigjiga Zone located at 630 km East of Addis Ababa at a latitude of 9°21'N and longitude of 42°48'E. The Woreda is characterized by unreliable and erratic rainfall with a precipitation ranging from 300 to 600 mm per annum, high ambient temperatures (>30°C), sparsely distributed vegetation dominated by *Cactus* and *Acacia* species, and bushy woodlands (Bekele, 2001). The altitude of this woreda ranges from 500 to 1500 m above sea level. The majority of the camel herders in the woreda are Somali ethnic groups. Numerically, camels are the most abundant domestic animals in the area followed by goats. This area is among the lowlands of the country where large population of camels is found and known for its camel milk production.

Camel milk sample for buttermaking were collected from Erer. Erer is situated approximately 25 km East of the town of Harar at an altitude ranging from 1300 m above sea level in the South to 1600 m above sea level in the North. It also represents one of the major camel milk producing areas in the country and has a semi-arid climate. There are two main rainy seasons in Erer, one during March to April and the other during July to September, with a mean annual temperature of 21.75°C. Shrubs and thorny bushes of *Acacia* and *cacti* origin dominate the vegetation (Bekele et al., 2002).

Milk sample collection

Before collection of camel and goat milk samples from Erer and

Table 1. Treatment combinations.

Treatments	Blend level (%)	Amount of milk (L)
T1	100% camel milk	4
T2	75% camel milk and 25% goat milk	4
T3	50% camel milk and 50% goat milk	4
T4	25% camel milk and 75% goat milk	4
T5	100% goat milk (control)	4

Hodle Kebele, respectively arrangements were made with local pastoral people to identify the areas with surplus goat and camel milk production. Milk samples were collected from camels and goats from 15 and 35 households, respectively. The camels used for milk collection were at their second stage of lactation and third parity whereas the goats were at their second stage of lactation and fourth parity. After collection, the milk samples were brought to the Dairy Laboratory of Haramaya University by placing it under ice box. For fermenting, the milk 15 airtight plastic Jerican containers (5 L capacity) were purchased from Addis Ababa supermarket. These containers were filled with either pure camel milk or camel milk blended with goat milk at different proportions and the milk samples were kept in the laboratory at room temperature until the required level of acidity, that is, pH of 4.13, was attained. A total of 20 L of camel milk and 20 L of goat milk were collected from the areas mentioned above for buttermaking. However, this amount of milk does not include the samples used for the microbiological analysis. Samples of milk for microbiological analyses were collected in sterilized stainless steel metal bottles from the above mentioned areas, that is, from the milk sources that were used for the buttermaking experiment and were mixed well before analysis.

Treatments

The experiment had five treatments, that is, T1, T2, T3, T4 and T5 as shown in Table 1. T1 was 100% camel milk, T2 was mixture of 75% camel milk and 25% goat milk, T3 was 50% camel milk and 50% goat milk, T4 was 25% camel milk and 75% goat milk and T5 was 100% goat milk, which was used as a control. The experiment was repeated three times for each parameter.

Experimental design

The design for the experiment was completely randomized design (CRD).
The model used was:

$Y_{ij} = \mu + ti + \varepsilon_{ij}$

Where
Y_{ij} = the j^{th} observation of the i^{th} treatment
μ = overall mean
t_i = the treatment effect (blend level) of the i^{th} treatment
ε_{ij} = the random error

Churning efficiency analysis of butter

For the churning efficiency analysis of butter samples fermentation time, churning temperature, pH of milk during churning, churning time and yield of butter were considered. For theses analysis, the standard procedure of International Livestock Research Institute Training Manual for Rural Dairy Technology (ILRITM, 1995), were followed. Churning was done manually by hanging the churn from a height (pole) and agitating the milk with up and downward movements.

Microbiological analysis of butter

For the microbiological analysis of butter samples total bacteria count (TBC), coliform count (CC), yeast and mould count (YMC), enterobacteriaceae count (EBC), lipolytic bacteria count (LBC) and proteolytic bacteria count (PBC) were considered. For these counts peptone, water was sterilized by autoclaving at 121°C for 15 min. Similarly, plate count agar (Oxoid, UK) used for determination of total viable organisms was sterilized by autoclaving it at 121°C for 15 min, violet red bile glucose agar (Oxoid, VG 37215: UK) used for determination of Enterobacteriaceae was sterilized by boiling. Tributyrin agar (High Media, Pvt. Ltd. LH0243) used for determination of lipolytic bacteria count, skim milk agar (Oxoid, UN0123: England) used for determination of proteolytic bacteria and potato dextrose agar (Oxoid, Uk) used for determination of yeast and mould count were sterilized by autoclaving at 121°C for 15 min, while violet red bile agar (Oxoid, V37720: Uk) used for determination of coliform count was sterilized by boiling (Richardson, 1985). For all tests, the media used were prepared according to the guidelines given by the manufacturers. Butter samples used for microbial analysis were collected aseptically in sterile bottles after churning. For total bacteria count (TBC), dilutions were selected so that the total number of colonies grown on a plate was between 10 and 300, while for CC dilutions that resulted counts between 15 and 150 per plate were selected. For Enterobacteriaceae, dilution levels that resulted in counts ranging between 20 and 200 colonies per plate were selected (Richardson, 1985). Eleven grams of the prepared butter samples were transferred into a sterile flask containing 99 ml of warm sterile peptone water (39 ± 1°C) to prepare a dilution of 10^{-1} from which decimal dilutions up to 10^{-3} were prepared. Finally, 1 ml melted butter sample was added into sterile test tube having 9 ml of peptone water.

Data analysis

Analysis of variance (ANOVA) was used for analyzing the churning efficiency and microbiological count data of butter samples using the General Linear Model (GLM) of SAS (1999). The microbiological count data was transformed to $\log_{10}$ values before statistical analysis. Significant differences were declared at 5% significance level.

RESULTS AND DISCUSSION

Churning efficiency of butter made from camel milk blended with goat milk

Pure camel milk (T1) took significantly longer ($P < 0.001$)

Table 2. Churning efficiency of butter made from camel milk blended with goat milk.

*Parameters	Milk type				
	T1	T2	T3	T4	T5
F time (days)	11.33 ± 0.58[a]	9.00 ± 0.00[b]	6.00 ± 0.00[c]	4.00 ± 0.00[d]	3.00 ± 0.00[e]
Ch T (°C)	28.00 ± 1.00[a]	22.00 ± 1.00[b]	17.00 ± 1.00[c]	14.00 ± 1.00[d]	12.00 ±1.00[e]
pH Mdch	4.13 ± 0.002[e]	4.43 ± 0.01[d]	4.65 ± 0.01[c]	5.16 ± 0.059[b]	5.65 ± 0.02[a]
Ch time (min)	121.67 ± 2.08[a]	80.33 ± 1.53[b]	29.00 ± 1.00[c]	19.00 ± 1.00[d]	13.00 ± 1.00[e]
Yb (g/L)	49.26 ± 8.41[d]	70.66 ± 3.72[c]	76.65 ± 12.67[c]	101.93 ± 4.79[b]	128.71 ± 1.96[a]

*F = fermentation; Ch T = churning temperature; pH Mdch = pH of milk during churning: Ch time = churning time; Yb = yield of butter; T1 = 100% camel milk type; T2 = 75% camel + 25% goat milk type; T3 = 50% camel + 50% goat milk type; T4 = 25% camel + 75% goat milk type and T5 = control (100% goat milk); Means with different superscript letters in a row are significantly different (P<0.001); values in the table are means ± SD of three replications.

time (11.33 days) to ferment as compared to the other milk samples (Table 2). On the contrary, pure goat milk (T5) took significantly shorter (P < 0.001) time (3 days) to ferment as compared to other milk samples. With increased proportions of goats' milk in the blend, the fermentation time T2, T3 and T4 kept on decreasing (Table 2). The longer fermentation time observed in pure camel milk (T1) in the present study is in line with earlier reports. Camel milk exhibits a two to three fold longer coagulation time compared with bovine milk (Farah et al., 2007). This is attributed to the differences in the size of fat globules that is mainly related to the availability of fat globules membrane (Farah and Ruegg, 1991). Camel milk coagulum was reported to contain a greater number of large casein micelles than bovine milk coagulum (Farah and Ruegg, 1991). Such an increase in the number of large casein micelles is due to the reduced casein content (Eksterend et al., 1980), consequently prolonging the coagulation time. The fermentation time of goat milk (T5) is similar to the fermentation time of 3days reported for cows' milk at Holeta and Selale in the central highlands of Ethiopia (Yilma et al., 2007).

Pure camel milk (T1) required significantly higher (P < 0.001) temperature for churning as compared to the other milk samples (Table 2). Whereas, the churning temperature of pure goat milk (T5) was significantly lower (P < 0.001) than the other milk samples (Table 2). With increased proportions of goats' milk in the blend, the churning temperature T2, T3 and T4 kept on decreasing (Table 2). The churning temperature applied for 100% camel milk in the present study is in agreement with the finding of Farah et al. (2007) who reported that butter can be made from camel milk by churning fermented camel milk at 20 to 25°C.

The pH of milk required for churning was significantly lower (P < 0.001) for pure camel milk (T1) than the other milk samples (Table 2). On the contrary, the pH of goat milk (T5) required for churning is significantly higher (P < 0.001) than the other (Table 2). With increased proportions of goats' milk in the blend, the churning pH kept on increasing (Table 2). This shows the effect of blending of camel milk with goat milk on butter making at higher pH. The pH of camel milk used during churning in the present study is in line with the churning pH of 4.6 for camel milk reported by Farah et al. (2007).

The churning time of 100% camel milk (T1) was significantly (P < 0.001) longer than the other milk samples (Table 2), while the churning time of 100% goat milk was significantly (P < 0.001) shorter than the others (Table 2). With increased proportions of goats' milk in the blend, the churning time T2, T3 and T4 kept on decreasing (Table 2). The reason for the different churning behavior of camel milk fat in comparison with goat milk fat can partly be attributed to the high melting point of camel milk fat. This seems to shift the ideal ratio of solid to liquid fat in the fat globules at a given temperature towards a point higher than that of goat milk fat. The different churnability observed could also be attributed to the reported small size of camel milk fat globules (Yagil, 1982). Small globules have a larger surface in relation to their mass that tends to increase their resistance for creaming up of butter from camel milk.

The yield of butter obtained from 100% camel milk (T1) was significantly (P < 0.001) lower than the other milk samples (Table 2). The yield of butter obtained from the blended milk sample (T4 and T5) were significantly (P < 0.001) higher than the other milk samples (Table 2); while no significant (P>0.001) difference were observed in yield of butter between T2 and T3 (Table 2). With increased proportions of goats' milk in the blend, the yield of butter kept on increasing (Table 2). Compared to goat milk butter, camel milk butter is white in color and is stickier and greasy in consistency. The possibility of making butter from pure camel milk observed in the present study, while others categorically stated that the preparation of butter from camel milk is not as easy as from milk of other animals owing to its unique milk fat properties, the fat is distributed as small micelle globules and apparently bound to the protein in the milk (Yagil and Etzion, 1980).

Microbiological quality of butter made from camel milk blended with goat milk

The coliform counts (CC) of butter made from pure camel

Table 3. Average microbial counts (log_{10} cfu/g) of butter made from camel milk blended with goat milk.

Microbial groups	Blend levels				
	T1	T2	T3	T4	T5
CC	3.07 ± 0.000^{a}	2.84 ± 0.005^{c}	2.72 ± 0.012^{d}	2.15 ± 0.002^{e}	3.02 ± 0.003^{b}
EBC	4.07 ± 0.001^{a}	3.25 ± 0.032^{b}	3.08 ± 0.016^{c}	3.05 ± 0.018^{c}	4.10 ± 0.009^{a}
TBC	4.35 ± 0.001^{d}	4.54 ± 0.007^{b}	4.51 ± 0.006^{c}	4.35 ± 0.009^{d}	4.72 ± 0.008^{a}
YMC	5.27 ± 0.004^{a}	3.51 ± 0.009^{b}	3.31 ± 0.026^{bc}	2.84 ± 0.002^{c}	3.72 ± 0.659^{b}
PBC	3.64 ± 0.002^{b}	3.31 ± 0.004^{c}	2.70 ± 0.029^{d}	2.19 ± 0.021^{e}	4.24 ± 0.002^{a}
LBC	5.29 ± 0.001^{a}	3.33 ± 0.003^{c}	2.95 ± 0.004^{d}	2.50 ± 0.062^{e}	3.41 ± 0.009^{b}

*CC = coliform count; EBC = enterobacteriaceae count; PBC = proteolytic bacteria count; LBC = lipolytic bacteria count; T1 = 100% camel milk type; T2 = 75% camel + 25% goat milk type; T3 = 50% camel + 50% goat milk type; T4 = 25% camel + 75% goat milk type and T5 = control (100% goat milk); Means with different superscript letters in a row are significantly different ($P < 0.001$); values in the table are means±SD of three replications.

milk (T1) and pure goat milk (T5) were significantly higher ($P < 0.001$) than the blended butter samples (Table 3). With increased proportion of goats' milk in the blend, the CC of T2, T3 and T4 butter samples kept on decreasing (Table 3). It may be due to antimicrobial activity of goats milk retard the growth of CC bacteria in blended butter samples. The coliform count observed in butter samples made from pure camel milk (T1) in the present study is higher than the results reported earlier by Mourad and Nour-Eddine (2006) who reported a CC range from 0.90 ± 0.15 to 1.66 ± 0.11 log_{10} cfu/ml of traditional butter (*Shmen*) made from camel milk in four regions of Algerian Sahara. The high coliforms counts of camel milk butter may be a consequence of the low level of hygiene during milking and handling of the milk prior to buttermaking.

The Enterobacteriaceae counts (EC) of butter samples made from pure camel milk (T1) and pure goat milk (T5) were significantly ($P < 0.001$) higher than EC of butter made from blended milk (T2, T3 and T4) (Table 3). With increased proportion of goats' milk in the blend the EC of T2, T3 and T4 butter samples kept on decreasing (Table 3). Enterobacteriaceae represent an important microflora of butter. Their presence in high number in T1 and T5 suggests that they were probably introduced from the external environment, that is, from the hand of milkers and storage containers (Harrigan, 1998).

The total bacterial count (TBC) of butter samples made from pure goat milk (T5) was significantly ($P < 0.001$) higher than TBC of the other butter samples (Table 3). The TBC observed in butter samples made from pure camel milk in the present study is higher than the finding of (Mourad and Nour-Eddine, 2006) who reported that total bacteria count in traditional butter (*Shmen*) made from camel milk in Ain-Safra, Mograr, Bechar and Saida regions of Algeria were 3.52 ± 0.12, 2.76 ± 0.19, 3.88 ± 0.23 and 3.54 ± 0.19 log_{10} cfu/g, respectively. The high count of total bacteria observed in the present study may be attributed to the use of raw milk samples for buttermaking.

The yeast and mould count (YMC) of butter samples made from pure camel milk (T1) was significantly ($P < 0.001$) higher than YMC of the other butter samples (Table 3). Butter made from blends of 25% camel milk and 75% goat milk (T4) had the lowest YMC (Table 3). On the other hand, there is no significant ($P>0.001$) difference in YMC T2, T3 and T5 (Table 3). In the present study, camel milk butter samples had high yeast and mould count which is in line with previous study that showed high YMC in butter made from camel milk (Rady and Badr, 2003; Mourad and Nour-Eddine, 2006). The presence of yeasts in butter might be attributed to contamination from air or to the lack of proper hygiene during buttermaking process, while the presence of molds indicates contamination of the product from air during the preparation of butter. Yeast and moulds are main causes for deterioration of butter (Fleet, 1990) and cause spoilage of butter by breaking down their components and liberating different acids and gases, which are responsible for subsequent change of its odour, loss of textural quality, economic losses from discoloration, poor appearance and off-flavors. In addition, some moulds and yeasts are capable of producing toxic metabolites known as mycotoxins such as aflatoxins, which are known carcinogens (Foschino et al., 1993). Warmer weather, inadequate refrigeration and improper storage are the principal causes of higher levels of contamination, increased diversity and change in yeast mycroflora in butter (Moreira et al., 2001).

Significance difference ($P < 0.001$) in proteolytic bacteria count (PBC) was observed between the butter samples (Table 3). The PBC of butter sample made from pure goat milk (T5) and pure camel milk (T1) were significantly ($P < 0.001$) higher than the rest (Table 3). With increased proportion of goats milk in the blend the PBC T2, T3 and T4 kept on decreasing (Table 3). Proteolytic bacteria cause bitter taste and bad odour through proteolytic reactions resulting in spoilage of butter (Sandrou and Arvantitoyannis, 2000).

The lipolytic bacteria count (LBC) of butter made from pure camel milk (T1) and pure goat milk (T5) were significantly higher ($P<0.001$) than the LBC of other butter

samples (Table 3). With increased proportion of goats milk in the blend, the LBC T2, T3 and T4 kept on decreasing (Table 3). Lipolytic bacteria are one of the spoilage microorganisms in butter and used to predicate the shelf life and the keeping quality of butter (Lejko et al., 2009).

In general, the results of the microbial analysis of butter samples indicate that butter made from pure camel milk (T1) had the highest microbial counts followed by butter samples made from pure goat milk (T5). The higher microbial counts of butter made from pure camel milk and pure goat milk could be attributed to the poor hygienic conditions followed during milking and handling of the milk by the pastoralists. This calls for the need for scrupulous hygienic measures during milking of camels and goats and during subsequent handling of the milk. The results of churning efficiency and microbial quality of blended butter samples (T2, T3 and T4) had improved. It could be attributed to blending effect of goat milk at different proportion. This calls for the need for blend of goat milk improving churning efficiency and microbial quality on camel milk. The present study revealed the possibility of making butter from pure camel milk by manipulating operating parameters such as churning temperature, pH of milk, degree of agitation and volume of the milk in the churn. However, one of the shortcomings observed during buttermaking from pure camel milk was that it takes very long time about 2 h to churn the milk. Thus, research is needed to decrease the churning time of camel milk by changing the different operating parameters.

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