Abstract
Traditionally, camel milk is consumed raw or fermented. Nowadays, the urbanized population is looking for more diversified products. New products like fermented milk with specific starters or camel cheese are available. The methodology for making new fermented products and cheese is presented. For making specific fermented products, lactic bacteria were identified, those having specific activity (gas production, taste, lactose degradation and acidification) were selected and their growth in industrial fermenters was assessed. Specific starters adapted for camel milk were put on the market for getting specific fermented products. The present communication was based on the experience in Kazakhstan were the consumption of fermented camel milk named *shubat* is very popular.
Regarding camel cheese, the combination of new chymozyme proposed by Hansen ©, named Chy-Max-M, the use of specific starters and camel milk with high controlled quality lead to the possibility to set up different types of camel cheese having their own organoleptic characters. Different types of soft cheese were proposed like Feta or Haloumi type camel cheese. The present communication is based on the experience in Saudi Arabia where many different kind of cheese technologies were tested. These two experiences open new opportunities for the dairy camel industry in the countries where camel is of high cultural and economic importance with specific consequences on genetic improvement program.

Keywords: camel milk, processing, genetic improvement, camel farming system

Introduction
Traditionally, camel milk is consumed raw by people living in remote areas where camels are reared. In some occasions, to extend its shelf-life, this milk is consumed under fermented form as it is the case in Central Asia known for fermented milk products which have been used for centuries (Doreau and Boulot, 1989; Konuspayeva et al., 2003). Other camel dairy products as yoghurt (Hashim et al., 2009), butter (Tesfamariam et al., 2013) or cheese (Jones-Abeiderrhamane, 2013) are not common and only recently set up with, for the moment, a weak development on the national markets and *a fortiori* on international market. These camel dairy products need still, some technological improvements for reaching the consumers. Yet, currently, the urbanized population is looking for more diversified products and the consumption of raw camel milk in this context is decreasing. The development of these new dairy products needs a better proximity between production areas and consumption basin. Consequently, periurban
camel farming systems are increasing to satisfy this growing urban demand (Faye et al. 2003). In the same time, the modernization of camel farming systems in those periurban areas (Faye, 2015a) leads to new challenges for using more adapted animals to produce these new products. Especially camels, passing from hyper-extensive farming systems to intensive ones, are obviously facing important changes including feeding systems, management of reproduction and milk productivity (Faye, 2015b) which is not without effect on the type of camel to be reared.

The present communication is focused on two experiences regarding innovations in camel milk processing and their indirect consequences on the genetic improvement program to be developed. The first experience deals with the improvement of fermented camel milk by using specific starters produced industrially. The second experience reports the setting up of camel cheeses by using new technology. In both cases, the technical innovations in milk processing accompany the intensification of the farming system and influence the genetic improvement needs of the camels.

Making a specific fermented camel milk: the experience of Kazakhstan

*The camel milk microflora biodiversity*

*Shubat* is the traditional fermented drink widely consumed in Kazakhstan (Konuspayeva and Faye, 2011). It is usually an homemade fermented camel milk especially, in the arid and semi-arid regions of the country. Traditionally, this product is processed from raw milks through fed-batch fermentation process. Microflora of *shubat* is composed of bacteria and yeast, which could have deep impacts on drink quality. Lactic acid bacteria and yeast were proven to be the main components in *shubat* starters. It is admitted that each environment had its own specific microflora. Thus, the identification and characterization of this microflora is of high importance for understanding and managing the fermentation process in order to get specific and new products. Indeed, *shubat* microflora plays major fermentative role in the aroma, texture and acidity. Moreover, microflora in fermented products plays also a therapeutic role on improvement of digestion properties and is responsible for antimicrobials properties (Arab et al. 2014).

Up to now, farmers prepared *shubat* by using ancestral techniques, which are an important part of the tradition. The diversity in microflora composition of conventional starters originating from the respective family environment resulted in high variability of *shubat* quality, not compatible with the necessary standardization of modern products for urban consumers. Consequently, studying the microflora of traditional fermented dairy products as *shubat* is useful for organizing industrial production of traditional fermented products with local strains. It is one important step in development of camel milk processing (Yateem et al. 2008; Ashmaig et al. 2009).

*Identification of natural lactic bacteria and yeasts in fermented camel milk*

Based on genotypic approach including PCR using three different pairs of primers (338f/518r; W001/23S1; Lac1/Lac2/Lac3) and 16S rDNA gene sequencing, three genus were identified in majority: Lactococcus, Lactobacillus and Enterococcus (for details, see Baubekova et al., 2015).

Finally, among 104 isolates, 79 were maintained in pure culture (71 bacteria and 8 yeasts). The milk samples coming from different regions of Kazakhstan, it was interesting to note the great difference in the microflora between products, selected from different locations. These
preliminary results confirm that the spontaneous microflora used for the preparation of traditional drinks differs depending on the locality, preparation conditions and other factors, which in turn leads to different qualitative characteristics of the finished product.

In a second step, three of the strains were selected because their biochemical properties (\textit{Lactobacillus fermentum} K5, \textit{Lactobacillus fermentum} K6 and \textit{Lactobacillus plantarum} K7) for testing their growth kinetic and characteristics, notably for measuring their produced biomass. This point was important for developing industrial culture in fermenters. Then, each culture was tested for technological suitability, acidity, bacterial colonization and organoleptic properties.

\textbf{Adaptation to industrial culture}

The transfer from research laboratory scale to industrial level needs specific equipment, especially bioreactor with at least 150 L capacity (figure 1). Such bioreactor can be fulfilled by up to 85 liters media. Starting culture is prepared in small starter bioreactor of 10L capacity.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{bioreactor.png}
\caption{Bioreactor for growing microorganisms in liquid media}
\end{figure}

The media used were selected on the base of bacteria optimal growth and convenient ratio cost/growth potential. Finally after different trials and literature review, six types of media were used.

The industrial parameters used for controlling the bacteria growth were aeration (oxygen saturation of the medium: 30\%, 50\%), periodic stirring (every 30 min, 5 min, 10 min), sowing dose of bacteria (5\%), incubation time (8 hours-12 hours). The quantification of growth was done by sampling every hour and morphology of bacteria was studied by microscopy.

\textbf{Marketing new starters}

The marketing of the product was based on a business plan including the strength of the project (use of natural and eco-friendly products, demand for standard fermented products, contribution to the national development of dairy products) and its weaknesses (no experience of the producers to use starters from market, no database of potential customers). However, the first step consisted in the protection of the activity by the deposit and registration of different patents: (i) Enriched culture medium for the cultivation of lactic acid bacteria, (ii) Method for obtaining a starter including specific lactic bacteria.

To register such products and to consider it as a “food product” by regular institutions, the lack of pathogenicity had to be proved. For that, several studies were implemented by independent organizations (the Academy of Nutrition in Kazakhstan) which has reported no pathogenicity of each bacterium isolated from the starter.
In the last step, the design and labelling of the package (figure 2) were registered in the relevant organization. The starters were marketed in two volumes, 5 and 10 grams per pack, and the 2-Bar code were obtained for each type of pack.

The publicity for this product was based on scientific publications, presentations in conferences and fears, as well as by mass media dissemination (TV interview, newspaper, films).

Figure 2. General labeling of package for shubat starter.

Making camel cheese at semi-industrial scale: the experience of Saudi Arabia

The challenges for camel cheese making
Traditionally, camel milk is not processed into cheese due to difficulties achieving coagulation with the most common bovine rennet (Farah and Bachmann, 1987). The difficulty in obtaining a coagulum with camel milk is due to its low concentration in k-casein which is responsible for clotting and for curd quality. The concentration is around 3% in camel vs 13% in cow milk (Kappeler et al. 2003). Thus, the first publications appearing in the 1980s regarding the possibility of making cheese from camel milk were focused on improving the coagulation process (Ramet, 1989; Mehaia, 1993). Different coagulation agents were proposed: bovine rennet enriched with minerals marketed under the name of Camifloc® (Ramet, 2001; Zubeir and Jabreel, 2008), plant extracts such as Zingiber officinale (Hailu et al. 2014), and crude gastric enzymes extracted from the camel’s abomasum (Boudjenah-Haroun et al. 2011). From the studies of Kappeler et al. (2006), recombinant specific camel rennet was elaborated and marketed under the name of Chymax-M1000®, Ch. Hansen®. Thus, since the recent availability of this recombinant coagulant, camel milk coagulation is no longer a constraint. Nowadays, the challenge for dairy scientists and cheese makers is to adapt the different known types of cheese technology to camel milk on a semi-industrial or industrial scale (especially in big integrated dairy camel farm having their own camel milk processing plant) and corresponding to the local taste.

Unfortunately, in most cases, camel cheese making has been carried out by scientists in their laboratory (Ahmed and El-Zubeir, 2011; Mohamed et al. 2013) rather than by professional
cheese makers on a semi-industrial or industrial scale (Jones-Abeiderrhamane, 2013). Different technological parameters for camel cheese making have been tested (Konuspayeva et al. 2014 and 2016), and mozzarella, white cheese or gruyere was produced, but the dissemination on market is still marginal.

**The camel cheese performance compared to cow cheese performance**

In the experience achieved in Saudi Arabia, the camel cheese technology was adapted for semi-industrial production and for the main types of soft cheese consumed in the Middle-East, i.e. Halloumi and Feta type. Firstly, to specify the cheese technology adapted to camel milk, it was essential to understand the behavior of this milk during cheese processing. For that, a comparison was made of the cheese making technology for camel and cow milk with the same level of fat and protein content. Secondly, a description of the technology adapted for camel soft cheese (Feta and Halloumi types) production was established on a semi-industrial scale.

To compare camel and cow milk processing, the composition of cow milk was adjusted to have the same concentration in fat and total nitrogen than camel milk and the same cheese making protocol was applied. The same rennet (Chy-Max M1000, Ch. Hansen ©) was used as coagulating agent at 50 µl/L concentration (without dilution) at 1000 IMCU. The same starter (thermophiles culture) was also used. This between-species milk comparison was carried out in order to assess camel and cow cheese yield in similar conditions and compositions. From 20 liters of milk for each species, the cheese raw yields were fairly comparable (7.4 ± 0.15 vs 7.3 ± 0.55 % for camel and cow milk respectively), but the corrected yield (according to dry matter) was 6.50 and 7.16 % respectively. The total nitrogen recovery appeared higher in camel cheese than in cow cheese, and opposite to fat recovery which was higher in cow cheese. However, calcium recovery was the same in both cheeses (table 1).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Camel cheese (n=5)</th>
<th>Cow cheese (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese Yield (kg/100kg⁻¹ milk)</td>
<td>7.4 ± 0.15</td>
<td>7.3 ± 0.55</td>
</tr>
<tr>
<td>pH</td>
<td>5.62 ± 0</td>
<td>5.39 ± 0.05</td>
</tr>
<tr>
<td>Dry Matter, g/kg</td>
<td>486.8 ± 5.65</td>
<td>469.75 ± 29.05</td>
</tr>
<tr>
<td>Ca recovery %</td>
<td>37.0 ± 0.2</td>
<td>36.6 ± 0.6</td>
</tr>
<tr>
<td>Total Nitrogen recovery %</td>
<td>84.3 ± 2.9</td>
<td>72.9 ± 0.35</td>
</tr>
<tr>
<td>Fat recovery %</td>
<td>57.4 ± 2.70</td>
<td>68.3 ± 3.4</td>
</tr>
<tr>
<td>DM recovery %</td>
<td>37.1 ± 2.55</td>
<td>35.0 ± 1.0</td>
</tr>
<tr>
<td>Non-Protein Nitrogen, g/kg</td>
<td>0.33 ± 0.11</td>
<td>2.74 ± 0.80</td>
</tr>
<tr>
<td>Non-Casein Nitrogen, g/kg</td>
<td>27.80 ± 0.14</td>
<td>10.65 ± 2.19</td>
</tr>
<tr>
<td>Proteins, g/kg</td>
<td>306.49 ± 3.90</td>
<td>243.16 ± 17.09</td>
</tr>
<tr>
<td>Caseins, g/kg</td>
<td>279.02 ± 3.66</td>
<td>235.25 ± 18.22</td>
</tr>
<tr>
<td>Fat/Total Nitrogen</td>
<td>0.52 ± 0.01</td>
<td>0.74 ± 0.08</td>
</tr>
</tbody>
</table>

Table 1. Comparative composition and recovery percentages of the main components in camel and cow cheeses curd processed from milk with a similar composition (mean and SD of triplicates) (From Konuspayeva et al., 2016)

**Camel cheese technology**
In the present communication, a short description of Feta and Halloumi cheese type technology is reported (for more details, see Konuspayeva et al., 2016). The behavior of the matrix “camel milk” being different, many adjustments were necessary.

For camel Feta cheese, a mother culture was used to accelerate the acidification process. After coagulation by ChyMax M1000, the clotting time was 3 min. 54 s ± 47 s on average. The coagulation started when the milk pH was below 6.00, to obtain a better quality curd. The final pH was 4.8 or slightly lower and was reached from 4 hours after the beginning of the process. After cutting and whey removal, moulding was achieved in moulds with two standpipes. In order to maintain thermophile starter activity and achieve faster acidification, the cheese curd had to be kept above 30°C. The yield was 9.31 ± 0.64 % kg/100kg milk. The dry matter content after 24 hours was 425.6 ± 38.2 g/kg.

Regarding camel Halloumi cheese, coagulation was started when the milk pH was below 6.10. After coagulation by ChyMax M1000, the clotting time was 3 min. 54 s ± 30 s on average. After cutting and whey removal, moulding was achieved in a fabric bag for 80-90 min. The cheese was pasteurized in its lactoserum whey at 80°C for 20 min. The Halloumi cheese was obtained after the cooking and salting procedure, drying and ripening for 24 hours. The final product could be consumed from 48 hours after making. The cheese was soft and supple. The yield was 8.22 ± 0.90 % kg/100kg milk i.e. lower values compared to Feta but with greater variability for yield. The dry matter content after 24 hours was slightly higher than that of Feta: 469.3 ± 73.8 g/kg.

Regarding the sensory assessment, it has been reported that the use of camel chymosin increased the sensory score values for most of the sensory attributes, whatever the type of cheese, in comparison to other clotting agents such as ginger or bovine chymosin, probably because of the higher proteolysis activity of camel chymosin (Moller et al. 2012). Camel Feta and Halloumi were not distinguished by their saltiness in spite of the different salting procedure and Feta cheese appeared fattier and tender than Halloumi. Tenderness by mouth or using a knife is usually linked to the fat concentration. The sensory properties of camel cheese could be improved by using more adapted starters from natural camel milk microflora (Jans et al. 2012). Thus, the identification, production and study of technological properties could be a useful step for selecting appropriate strains for camel cheese processing as proposed in the first part of this communication.

The products are packaged and sold in small shop (figures 3 and 4). Moreover, training workshop was organized to disseminate the know-how to the private sector.
Which consequences for genetic improvement?

A new camel for new camel farming systems and expected performances?
The camel is a multipurpose animals and among the domestic animals, one that makes the most diverse services to human. However, face to the new challenges of dairy production (both for quantitative and qualitative performances), the selection targets are not similar to that of camels reared under traditional way. Any selection programme has to be adapted to the purpose of the farming. In extensive system (nomadic or transhumant), the main character to be selected are the adaptation to high mobility, low nutritive value diet, spaced watering, random milking and high longevity while in intensive systems, it is more important to develop adaptation to high energy diet, spaced meals with high quality protein, management of the effort (for racing camel) and high milk potential as well as adaptation to milking machine.

In spite of the low selection pressure observed on camel, some progress was observed at the world level even if the performances are still low. Since 50 years, the growth for indigenous carcass was 4.6% and 8.4% for carcasses slaughtered in abattoirs. Regarding the milk, the productivity increased by 38.3% for milk yield only (source FAOstat). However, this progress is not sufficient to meet the growing demand of the population living in arid lands.

Thus, there is an urgent need for assessing the performances’ potential of camel and consequently, for studying the camel biodiversity at world level, in order to identify animals and “breeds” with high potential for fattening, milk production or velocity. This biodiversity has been already explored in various countries around the world, showing the genetic structure of the camel population and leading to the conclusion that the camel biodiversity in the world find its origin in the genetic diversity of camel population in Arabian Peninsula (Faye et al., 2011).

In such context, the recent implementation of the Camel Consortium for Genetic Improvement and Conservation (CC-GIC) is an important step for the international scientific community in order to contribute collectively to the establishment of convenient world strategy for increasing camel performances and promoting more adapted animals in intensive production. Regarding the dairy yield and processing, the main challenge is the selection of dairy camel with high potential, higher protein content in milk and udder morphology adapted to machine milking.

Dairy productivity, milking machine and udder morphology selection
While it is admitted that camel has the ability to produce more milk than local cow in similar feeding and climatic conditions, camel milk productivity is not well known. Data from the literature are scarce, mainly issued from observations in research stations, and more rarely from pastoral areas where performance monitoring is not common. However, with a range of 1000 to 12000 liters per lactation according to different sources (Faye, 2004) a potential for selection on that criterion could be supposed. Such selection is possible but rarely achieved. The selection has to be oriented to the dairy yield daily, but also to the shape of the lactation curve marked in camel by a late and smooth peak (3-5 months), a high persistency (85-90%) and a long lactation length up to 18 months (Musaad et al., 2013). Obviously, feeding, reproduction status, the
seasonal conditions and the farm management could have an impact on the milk performances in addition of genetic selection. The dairy improvement could be accelerated by the identification of specific genes and biotechnology of reproduction like embryo-transfer, both regarding milk yield and protein content in milk.

Regarding machine milking, considerable recent studies are available (Atigui et al., 2014a, b, and 2015; Ayadi et al., 2013; Hammadi et al., 2010; Wernery et al., 2004). Machine milking has been developed initially by applying similar parameters than for cow in spite of big differences in the lactation physiology of camels. The recent studies conducted to a better adaptation of the technical parameters of milking machine (vacuum level, pulsation rate, udder stimulation, diameter of clusters, etc.). Efficient milking are related to the good milkability of animal (degree to which animals can be machine milked). Such good milkability is affected by different factors like teat and udder morphology, milking machine parameters, animal temperament, milkmen’ behavior or milking management. If milking machine parameters or milking management are under the responsibility of the milkmen, teat and udder morphology, animal temperament and milking facility can be improved by genetic selection. Regarding milking facility, milk partitioning, residual milk and milk flow traits during milking are generally used to evaluate machine milkability (Ayadi et al., 2015a). Easily milked camels have a smaller proportion of machine striping milk and residual milk than those that are harder to milk.

Udder morphology traits determine several aspects of manageability (time of milking, suckling difficulties, falling off of the clusters, etc…). Therefore, mammary traits must be considered as economically important traits in selected flocks. Udder morphology traits had a positive correlation with milk yield and can be adopted in breeding programs for improving milk production in dairy camels (Atigui et al., 2014a; Ayadi et al., 2015b). Poorly shaped teats and badly shaped udders are a recipe for reduced profitability and productivity of the camel enterprise. It is subsequently important to identify the typology of udders to make more informed breeding and herd management decisions that improve udder durability and camel longevity. In the monitoring achieved in Saudi Arabia, teat shape was globular in 47% of the cases, followed by pear shape (34%) and pendulous (19%). It has been reported that camels with pendulous shape udder and blew up teats may increase labor, incidence of mastitis, calf mortalities and falling off of the clusters during machine milking. From the preliminary studies achieved in camel, a linear scoring has been proposed (Ayadi et al., 2015b) as a tool of selection by morphology for improving their machine milkability (figure 5)
Figure 5. Linear udder scoring in lactating dromedary camels to be used for genetic selection

<table>
<thead>
<tr>
<th>Traits</th>
<th>Score</th>
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<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Udder Depth</td>
<td>Shallow</td>
</tr>
<tr>
<td>Udder Floor inclination</td>
<td>Descending</td>
</tr>
<tr>
<td>Teat Shape</td>
<td>Funnel</td>
</tr>
<tr>
<td>Teat Length</td>
<td>Short</td>
</tr>
<tr>
<td>Teat Width</td>
<td>Narrow</td>
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</tbody>
</table>

**Conclusion**
The development of new dairy products based on camel milk accompanies the emerging demand of more urbanized population in products with high added-value, good nutritive quality and sufficient safety. Such demand pushes the camel producers to modernize their farming system and consequently the stakeholders to improve the performances of their camels. Selection programs must be implemented in the “camel countries” for a better adequacy between the growing demand in camel dairy products and ability of producers to deliver in the market sufficient high quality processed milk.

**References**
Kappeler S., Farah Z., Puhan Z., 2003. 5'-Flanking regions of camel milk genes are highly similar to homologue regions of other species and can be divided into two distinct groups. J Dairy Sci., 86, 498-508