

Current Trends in Buffalo Milk Production

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Abstract: Between 1961 and 2018 on the total number of dairy ruminants, the percentage of buffaloes and the quantity of milk produced by them had an increasing trend from 3.7% to 5.2% and from 5.4 to 15.7%, respectively; this value on the world total "cow milk + buffalo milk" rose to 18.64%.

In the Asian continent, buffaloes' incidence on the total number of dairy ruminants increased slightly (from 10.2% to 11.7%) while the percentage of cattle fell from 38% to 26.4%. In the same period, the percentage of buffalo milk decreased from 44.6% to 36.9%, while cow milk shares increased from 55.4% to 63%.

The percentage of milk produced in Pakistan, India, Nepal (after 2010), and especially in Egypt showed a downward trend. In Italy, the trend has always been increasing.

The market price of buffalo milk in developing countries does not compensate for costs which are 15% higher than cow's milk, if only the cost of feeding is considered, and increases to 40% when the difference in kg of milk equivalent between the two species is about 900 kg per lactation. A reduction of the production gap between the two species is difficult to be achieved because the genetic improvement of dairy cattle is performed in industrialized countries with higher financial support. Therefore, a marketing effort is needed to make well-differentiated buffalo products with specific and well-received sensory properties. In this regard, it should also be noted that δ -valerobetaine, a bioactive molecule beneficial for human health, is present in buffalo milk and meat in higher quantities than in cow's milk.

Keywords: Buffalo milk, world buffalo milk, italian buffalo milk.

INTRODUCTION

Before the last ice age, the buffalo was present in Europe, subsequently migrated to the tropical and sub-tropical areas of Asia, its place of origin. Starting from the eighth century AD, the Arabs introduced it to Egypt and then to southern Italy [1]. At the end of the 1800s, presumably in 1895, following a shipwreck of a French ship carrying buffaloes from India to French Guiana, buffaloes landed on the island of Marajo at the mouth of the Amazon River which has an area equal to that of Switzerland [2].

Less cosmopolitan than cattle, buffalo showed a higher rate of increase than cattle: + 234% (206.600.00 / 88.321.807) vs. 158% (1489744504 / 942175069) between 1961 and 2018. This finding suggests that the buffalo species are meeting the favour of entrepreneurs because it represents a new economic opportunity.

In the present study, FAO's official data [3] have been used, and the data of the planet, Asia, and the countries with the largest dairy buffalo heritage (India, Nepal, Pakistan, Egypt) have been examined. Italy was also examined, which is an example of intensive buffalo farming in the world scenario.

INCREASE IN THE BUFFALO POPULATION IN THE WORLD AND ASIA

When considering the numerical increase of buffaloes and the increase in the amount of buffalo milk, it must be borne in mind that the species is present mainly in Asia, where the human population had an increase of over 400 million inhabitants in the last 10 years to which it has necessarily followed an increase in the consumption of products of animal origin.

In particular, based on the data from FAO, which are available since 1961 (Table 1), it emerged that between 1961 and 2018 (Figure 1), the percentage of buffaloes reared. The quantity of milk produced on the total dairy ruminants (cattle, buffalo, goats, sheep, dromedaries, and camels) had an increasing trend from 3.7% to 5.2% and from 5.4 to 15.7%, respectively. Buffalo milk in 1961 represented 5.69% of the world total "cow plus buffalo milk" (BM + CM). This incidence increased to 18.64% in 2018 (Figure 2). Figure 3 shows a comparison between the percentage of world buffalo and cow milk productions.

Simultaneously, the population of cattle and the relative milk production decreased (Figure 4) while the opposite is observed for the buffalo (Figure 5).

In the Asian continent, where 97.41% of the buffalo population is present, the incidence of buffaloes on the total of dairy ruminants is slightly increased (from

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Table 1: World Buffalo and Cow Milk Production (the Difference to 100 is Represented by the Sum of Camel Milk + Goat + Sheep)

year	buffalo milk		cow milk	
	tons	% buffalo milk	tons	% cow milk
1961	17.858.061	5.19	313.626.619	91.12
1970	19.593.886	5.00	359.280.844	91.67
1980	27.525.084	5.91	422.351.163	90.67
1990	44.076.214	8.13	478.539.902	88.22
2000	66.650.866	11.50	489.874.522	84.53
2010	92.468.193	12.78	601.868.328	83.18
2018	127.338.184	15.10	683.217.055	81.04

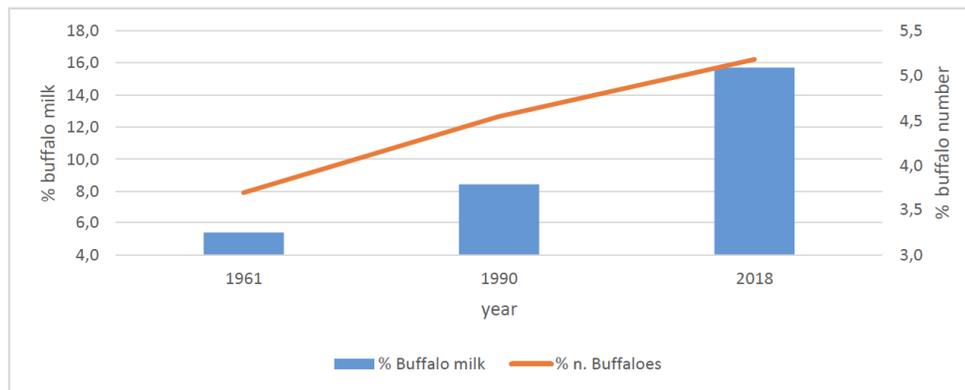


Figure 1: World percentage of milk and number of buffalo/(total of dairy ruminants) between 1961 and 2018.

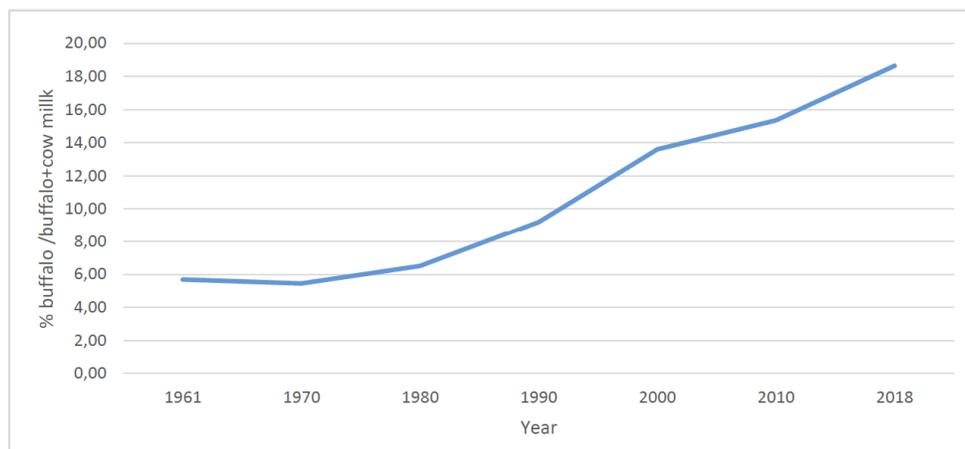


Figure 2: Percentage (%) of world buffalo milk production on the total cow + buffalo milk.

10.2% to 11.7%) while the percentage of cattle decreased from 38% to 26.4%. Simultaneously, buffalo milk decreased from 44.6% to 36.9%, while cow's milk increased from 55.4% to 63% (Figure 6).

Buffalo milk production in India, Pakistan, Egypt, Nepal, and Italy

In 2018 72.1%, 22.07, 1.67%, 1.05%, and 0.19% of buffalo milk in the world were produced in India,

Pakistan, Egypt, Nepal, and Italy, respectively (Figure 7). However, Italy shows a growing trend while Pakistan, India, and especially Egypt show a decreasing trend. In Nepal, the percentage increased until 2010 and subsequently decreased.

If the total also includes milk produced from camel, goat, and sheep, this percentage value is 5.19% and 15.1% in 1961 and 2018, respectively (Figure 2). In the exposure, the percentage values refer to this total.

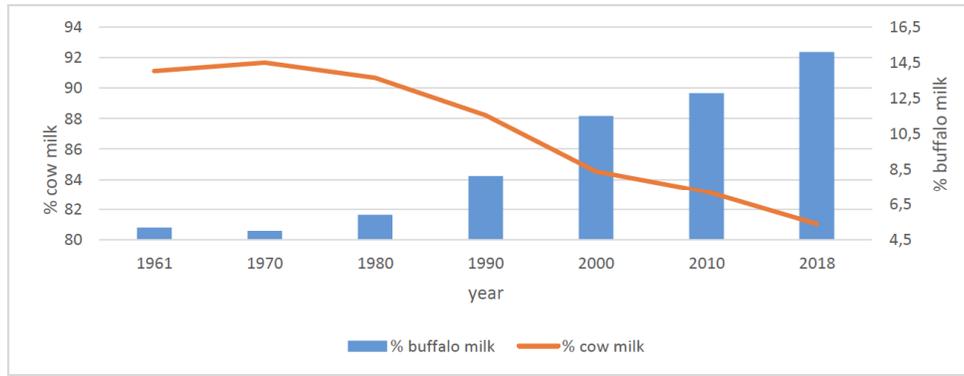


Figure 3: Percentage of world buffalo and cow milk production (the difference to 100 is represented by the sum of camel milk + goat + sheep).

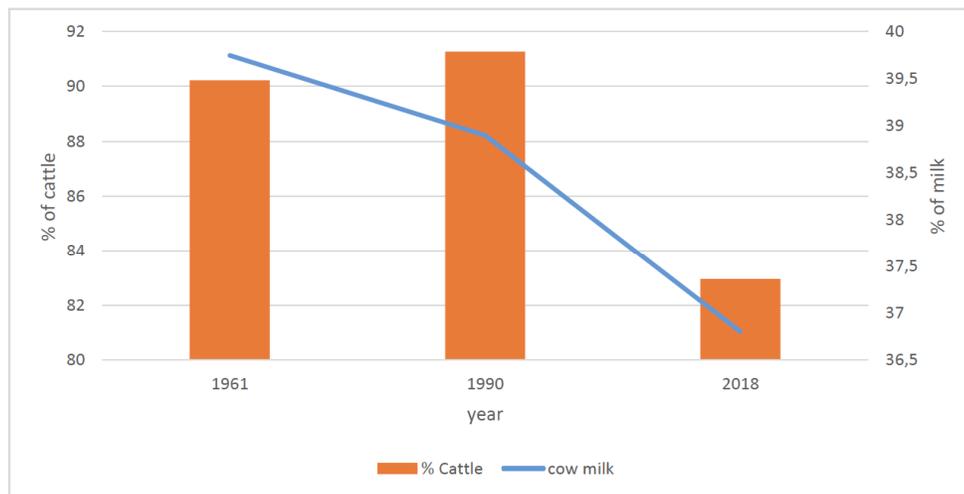


Figure 4: World percentage of milk cow and number of cattle/(total of dairy ruminants) between 1961 and 2018.

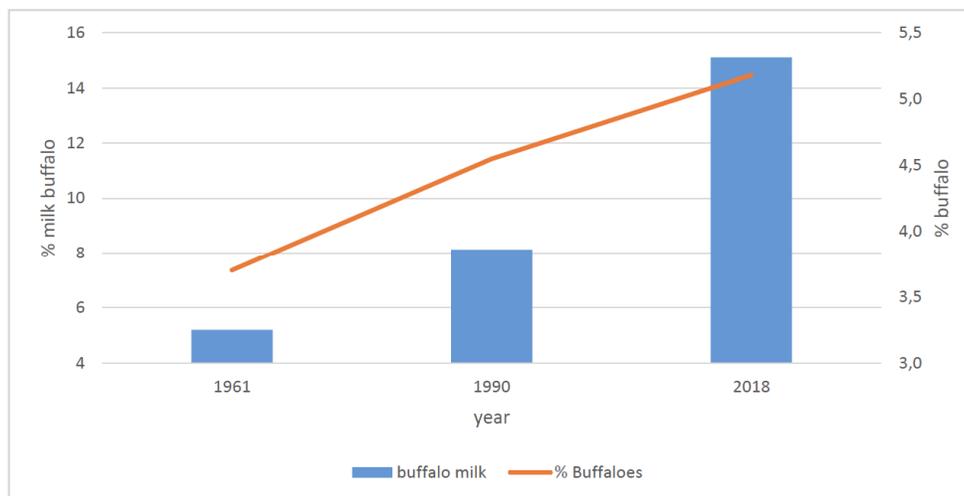


Figure 5: World percentage of milk and number of buffalo/total dairy ruminants between 1961 and 2018.

In 1961 the buffalo milk represented 6.12% of total world production, including buffalo and cow (BM + CM) milk [3]. In 2018 the above percentage progressively increased up to 18.64% (Figure 1).

If the production of buffalo milk from these countries is compared to the milk produced by all the species (Figure 8), it is clear that the milk produced in the other countries shows the same trend described in Figure 6.

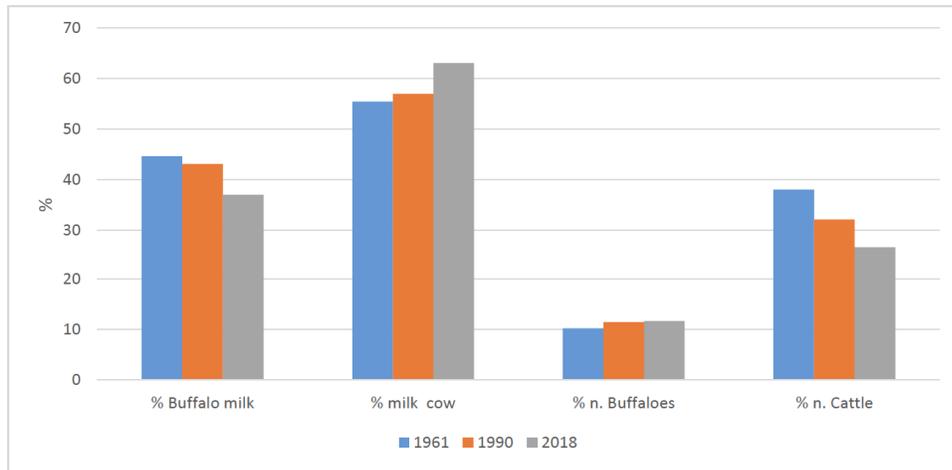


Figure 6: Trend (%) of the buffalo and cattle population present in Asia and trend in the quantity of milk produced by the two species between 1961 and 2018.

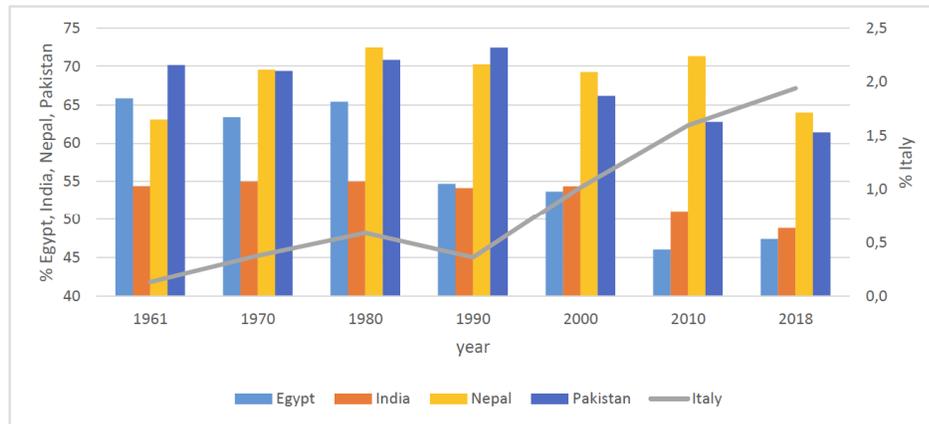


Figure 7: Percentage India, Pakistan, Egypt, Nepal and Italy buffalo milk on the total of the world buffalo milk.

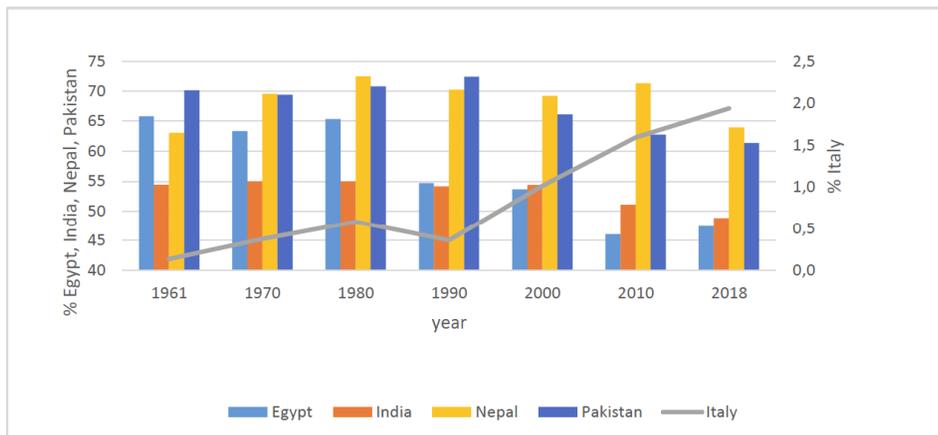


Figure 8: Percentage of buffalo milk out of the total produced by dairy ruminants between 1961 and 2018 in Egypt, India, Nepal, Pakistan, and Italy.

Percentage of buffaloes raised and buffalo milk produced in India, Pakistan, Egypt, Nepal, and Italy.

In India, the country that produces 70% of the buffalo milk globally [3], the buffalo population

increased between 1961 and 2018 (Figure 9) while the percentage of buffalo milk decreased. A similar trend has been observed in Pakistan (Figure 10) and Nepal (Figure 11). On the other hand, in Egypt (Figure 12),

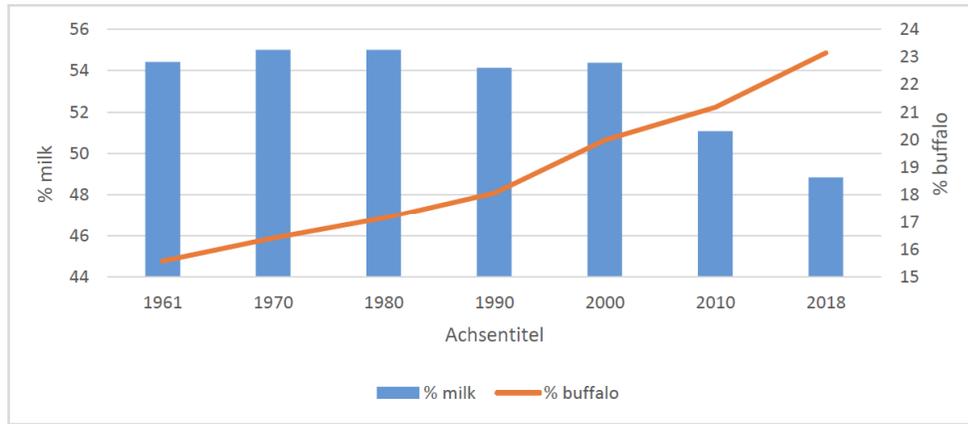


Figure 9: India: percentage buffalo number and milk production out of the total animals bred and milk produced from 1961 to 2018.

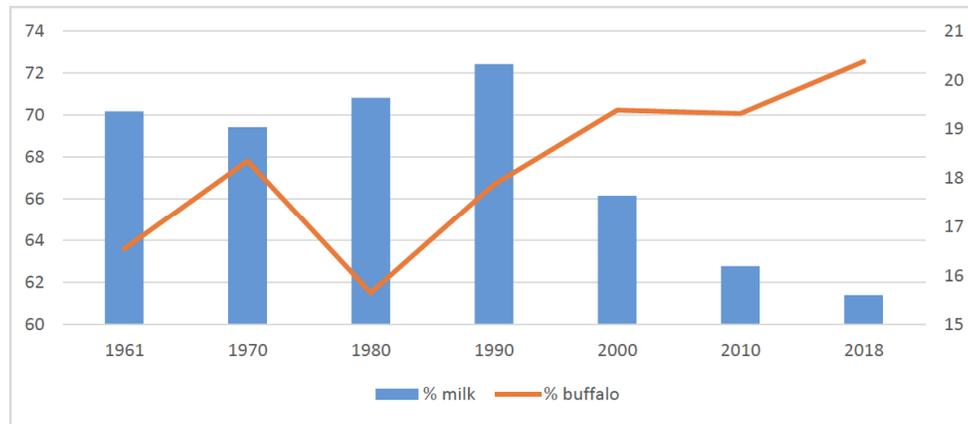


Figure 10: Pakistan: percentage buffalo number and milk production out of the total animals bred and milk produced from 1961 to 2018.

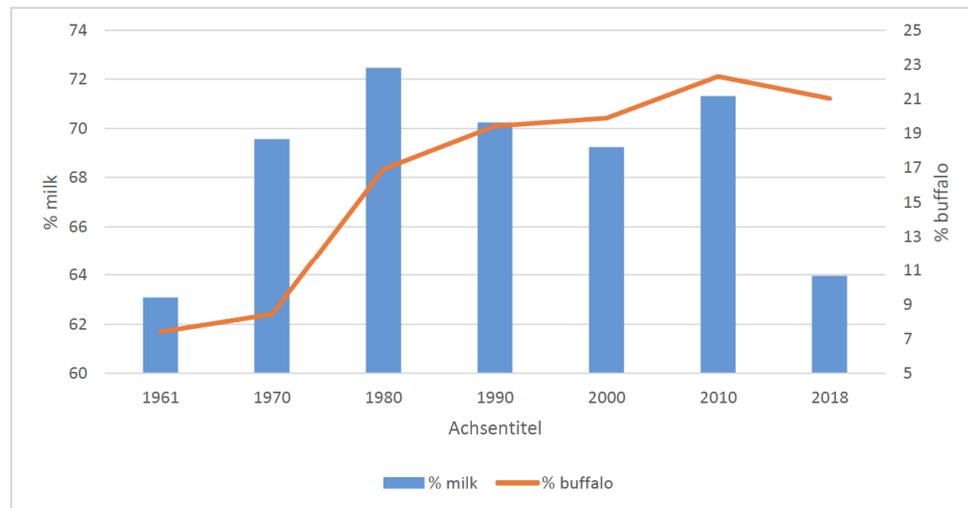


Figure 11: Nepal: Percentage buffalo number and milk production out of the total animals bred and milk produced from 1961 to 2018.

the percentage of buffalo milk and the number of buffaloes decreased, while in Italy (Figure 13) both increased.

From the comparison of Figures 14 and 15, it can be observed that the incidence of buffalo milk is not

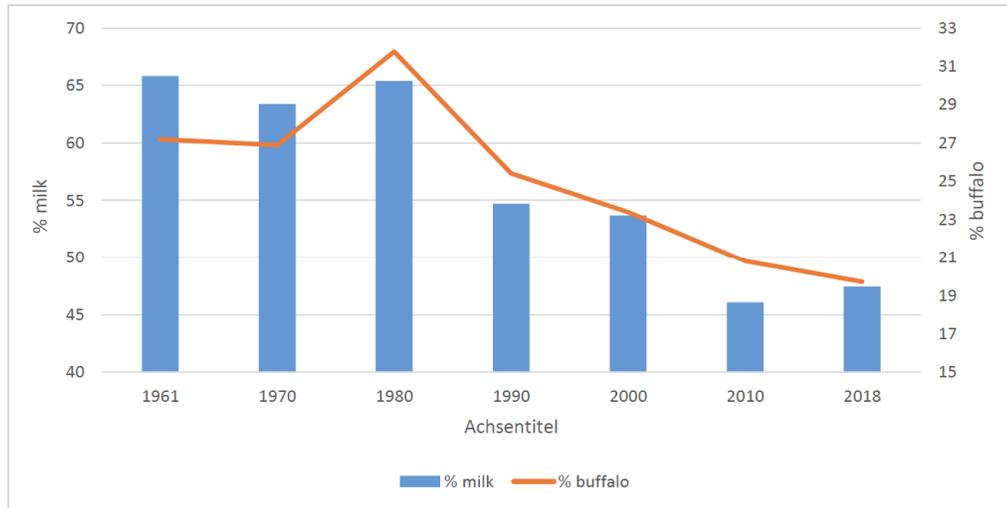


Figure 12: Egypt: percentage buffalo number and milk production out of the total animals bred and milk produced from 1961 to 2018.

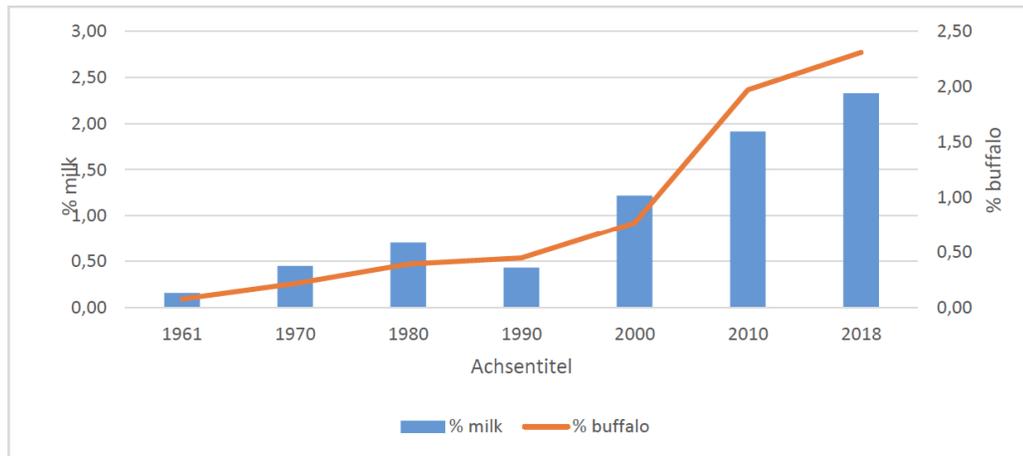


Figure 13: Italy: percentage buffalo number and milk production out of the total animals bred and milk produced from 1961 to 2018.

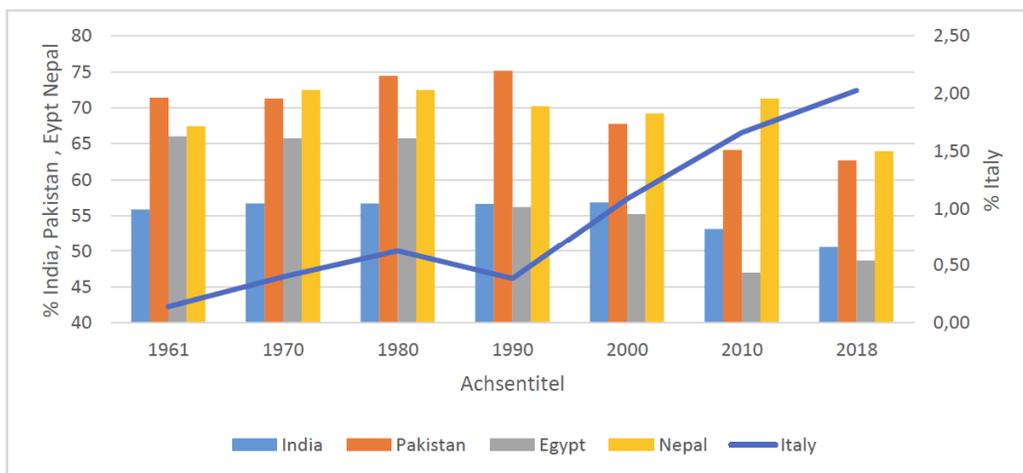


Figure 14: Percentage of buffalo milk on the buffalo+cow milk from 1961 to 2018 in India, Pakistan, Egypt, Nepal, and Italy.

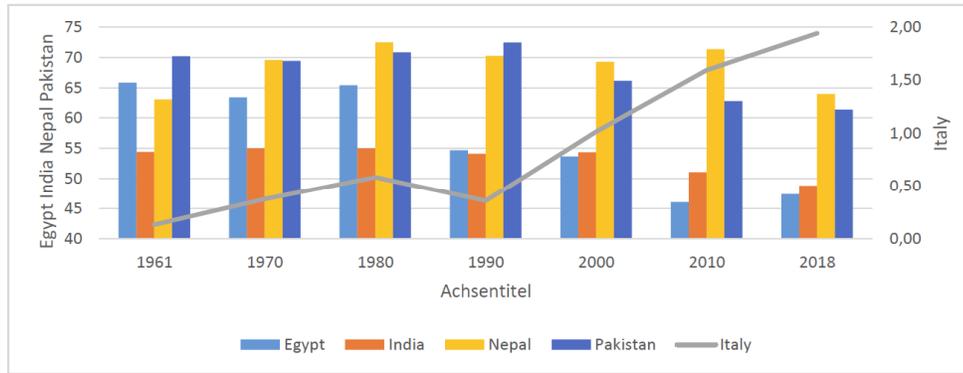


Figure 15: Percentage of buffalo milk on total milk produced by dairy ruminants in Egypt, India, Nepal, Pakistan, and Italy from 1961 to 2018.

different if it is compared to the sum of buffalo and cow milk or the total milk production of dairy ruminants.

Possible reasons underlying the current trends in buffalo population and milk production at world level

From the scenario described in the present study it emerges that, despite the increase in population and production of buffalo milk in the countries where the species is mostly present, the increase in the population does not always coincide with a higher incidence of buffalo milk on the total milk produced by all dairy ruminants. For example, in India, the percentage of cow milk increased despite the decrease in cattle, while buffalo milk decreased despite the numerical increase of this species (Figures 16 and 17).

The increase in the buffalo population recorded in tropical and subtropical countries can be attributed to

the species' higher adaptability to the hot and humid environments where water and mud are available. Thus the animals can wallow and to the lower incidence of diseases. These factors led the breeder to prefer buffaloes to dairy cattle, especially on family farms. In temperate continental areas where the environmental temperatures do not penalize dairy cattle's production efficiency, the buffalo population has decreased by 99% because the production cost of cow milk is markedly lower. The ability to efficiently use coarse forage, which is often mentioned as a positive aspect of buffaloes, has not proven to be always true and is entirely irrelevant to this end [4, 5]. The Italian situation is entirely different due to the high market value of milk.

In countries where the incidence of milk production has decreased, the price of buffalo milk is less than twice as high as cow's milk (Table 2), while in Italy, it is

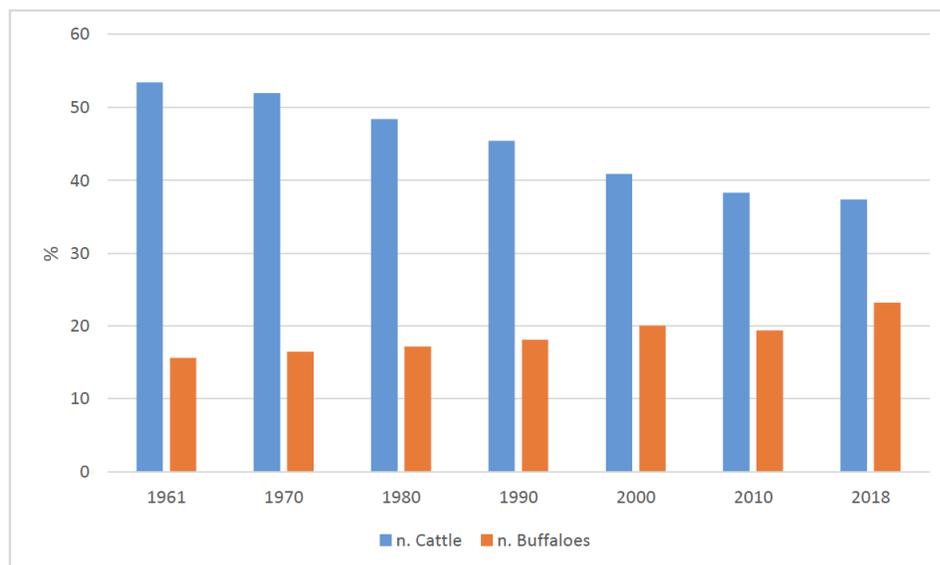


Figure 16: India: percentage buffalo and cow populations compared to the total number of dairy ruminants between 1961 and 2018 in India.

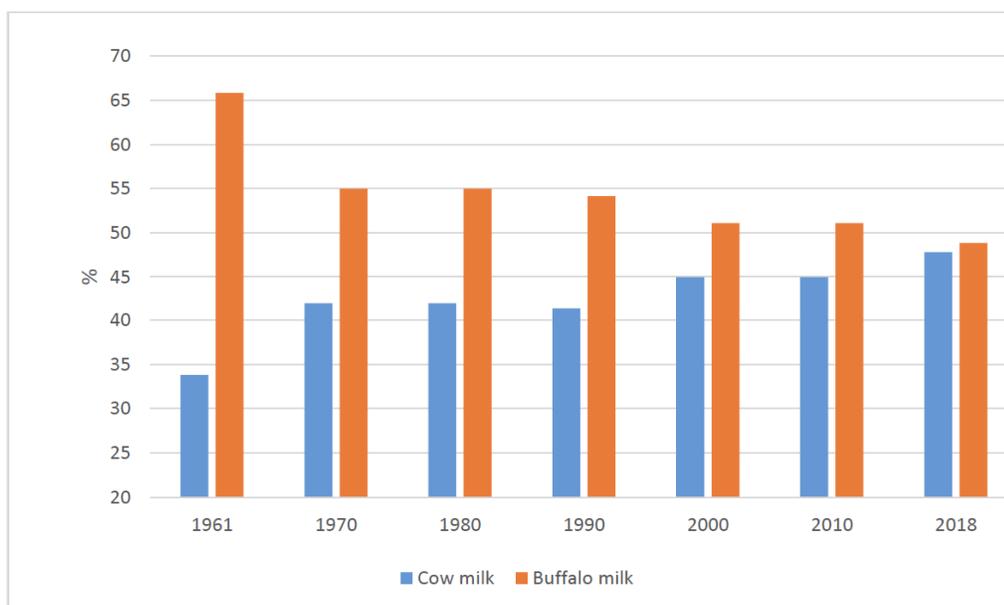


Figure 17: India: percentage of buffalo and cow milk compared to the total milk produced by dairy ruminants between 1961 and 2018 in India.

Table 2: Price of Buffalo and Cow's Milk, National Currency and Source Consider the Yield in Mozzarella (25.5% and 13.0% for Buffalo and Cow Milk, Respectively) with a Ratio of 1.96 (25.5 / 13) it is Clear that Even a Payment that Considers the ECM may not Sufficiently Reward the Higher Quality of Buffalo Milk

Country		Currency		Source
India	cow	Indian Rupee	35	https://dir.indiamart.com/indianexporters/dairy.html
	buffalo	Indian Rupee	55	
	ratio		1,571	
Pakistan	cow	Pakistani Rupee	109	https://www.olx.com.pk
	buffalo	Pakistani Rupee	140	
	ratio		1,284	
Nepal	cow	Nepalese Rupee	70	https://kathmandupost.com/money/2017/05/20/milk-prices-hiked-up-by-9-14-percent
	buffalo	Nepalese Rupee	80	
	ratio		1,143	
Egypt	cow	Egyptian pound	2,613	Khalil, M. A. I. and A. I. M. Ahmad, 2013, Milk production and marketing efficiency for dairy farms (Case study in Kafer El-Sheikh –El-Beheira –Qena) governorates. J. Animal and Poultry Prod., Mansoura Univ., Vol.4(2): 107 -115
	buffalo	Egyptian pound	3,723	
	ratio		1,425	

sold at a price which is more than three times higher than cow's milk. This is the main reason explaining the increase in the buffalo milk/cow's milk ratio in Italy (from 0.6% to 1.6%) and the decrease of the same ratio in other countries between 1961 and 2018 (Figure 15).

The price of buffalo milk in developing countries depends only on the fat and protein content, while in Italy, it is also related to the organoleptic characteristics of mozzarella cheese. It should be stressed that in recent years the value of milk is no longer expressed as FCM (milk corrected for fat) but as ECM (milk corrected equivalent), which also considers the protein

Table 3: Production (kg) and Milk Forage Units Needed (Including those of all Production Phases and Replacements) to Produce 1 kg of ECM and Cheese

	kg		Milk Forage Units / kg	
	milk	ECM	ECM	cheese
cattle	8700	8178	1,06	7,33
buffalo	2200	3641	1,29	8,29
Difference between cow and buffalo	6500	4537	-0,23	-0,96
cattle	3000	2896	1,57	14,44
buffalo	1600	2493	1,74	12,34
Difference between cow and buffalo	1400	403	-0,17	2,1
cattle	2400	2510	1,86	17,32
buffalo	1200	1870	2,09	15,01
Difference between cow and buffalo	1200	447	-0,23	2,31
cattle	2200	2124	1,99	18,62
buffalo	800	1246	2,8	20,35
Difference between cow and buffalo	1400	878	-0,81	-1,73
cattle	2400	2317	1,86	17,32
buffalo	1400	1558	1,89	13,48
Difference between cow and buffalo	1000	759	-0,03	3,84
cattle	1800	1738	2,34	22,11
buffalo	1000	1558	2,37	17,14
Difference between cow and buffalo	800	180	-0,03	4,97

content in addition to fat [6]. Compared to cow milk, the ECM value of buffalo milk is 60% higher but if we

If buffalo milk was paid twice as much as cow's milk, the trend currently in place in developing countries, in my opinion, could be attenuated but not reversed. Table 3 shows that, if we consider only the feeding costs (including those of all the production phases and the breeding of replacements), for the production of 1 kg of milk more Milk Forage Units (MFU) are required by buffaloes than cattle if the difference in ECM produced by the two species ranges between 4500 kg and 878 kg. Conversely, below these values (759 - 180 kg), the amount of UFL / kg of cheese is higher for cow's milk. Therefore, in this case, the cheese produced with buffalo milk may be more profitable (personal data). However, when the difference between the kg of milk produced by the two species lowers to less than 1000 kg, the amount of MFU needed to produce 1 kg of milk is similar. Compared to cow milk, the ECM value of buffalo milk is 60% higher but if we consider the yield in mozzarella that for buffalo milk is 25.5% while for cow milk it is 12.5 - 13.5% ($25.5 / 13 = 1.96$) it is clear that even a payment that considers the ECM does not reward the higher quality of buffalo milk.

Therefore, to increase the economic returns from buffalo milk and make it more competitive, it is necessary to focus on its organoleptic qualities and effective improvement of the sensory quality of the corresponding cheese; this should be the main goal of genetic improvement. Both genetic improvement and sensory quality may play a fundamental role in promoting the demand for buffalo milk/cheese and increasing farmers' income.

In Italy, almost all the milk of these species is used to produce cheese, and its remuneration is influenced by seasonality, moreover, with the same seasonality, by the yield. In Italy, buffalo milk is paid 3.5 to 4 times more based on year than cow's milk. In the European countries (Bulgaria, Romania, the former Yugoslavia, and Greece) which did not improve the organoleptic properties and the productive process of the buffalo milk, the buffalo population in 2018 decreased by 99 % compared to 1961, while the Italian buffalo milk that in 1961 represented 5% of the buffalo milk produced in Europe in 2018 represents 95%.

The profitability of buffalo milk in developing countries depends on fats and proteins' content, while the organoleptic characteristics of both milk and cheese are irrelevant. In developing countries, buffalo

Table 4: Cheeses Produced with Buffalo Milk

Type of cheese	Country of Production	type of milk
Mozzarella di bufala campana	Italy	only buffalo milk
fresh curd	India, Pakistan, Sri Lanka e Nepal	Not only buffalo milk
Domiaty, Istanboly	Egypt	Not only buffalo milk
Chena	Bangladesh and India	Not only buffalo milk
Nguri	Cina	Not only buffalo milk
Dangke	Indonesia	Not only buffalo milk
Kesong puti	Filippine	Not only buffalo milk
kaymak	Egypt, Turkey and Mid-East countries	Not only buffalo milk

milk is often mixed with cattle, sheep, and goats, and used to produce yogurt, kaymak, and other types of undifferentiated commodity cheeses (Table 4). In total, buffalo milk is the component of about 8 products in addition to yogurt. This number is markedly lower than that of cheeses obtained from cattle, sheep, and goats. This likely depends on the fact that in some countries where buffalo is widespread (e.g., Southeast Asia), there are no traditional dairy products, possibly because most adults are lactose intolerant. The adult population's lactose tolerance is due to a genetic mutation that spread about seven thousand years ago in Europe, and then in the Middle East and Africa. Tibetan, Mongolian, and Uyghur nomadic populations normally consume milk and dairy products, whereas, in China, soy and tofu are more commonly used to cover human protein needs. However, the constant exchange with the West is spreading the consumption of dairy products in the east of the world.

Critical points for buffalo milk production in developing countries

Mozzarella cheese, a DOP product which is now the third Italian cheese in terms of consumption, is made with only buffalo milk. However, the Italian example cannot be easily extrapolated to other countries for both cultural and economic reasons. Unlike Italy, most of the buffalo milk is intended for direct consumption in developing countries because, due to the particular taste, which depends on the higher lipid/protein ratio, it is preferred to cow's milk. However, this preference is more common in rural areas, whereas in recent years, as also occurred in the past in industrial countries, the population is progressively migrating to big cities. Besides, in 2050 it is expected that 70% of the population will move to megalopolises (<http://www.virtualcentrte.org>) where food purchase will not take place directly in the buffalo farms but in shops where cow's milk will be probably cheaper.

A non-secondary weakness is the seasonality of the species, which does not allow buffalo milk's constant presence on the market [7-10].

As it has been done for years in Italy [11], the herds' reproductive activity should be adapted to the needs of the market. To this aim, a fair comparison between breeders and processors is needed to compensate for the higher costs needed to provide a constant presence of buffalo milk on the market.

In order to prevent a further reduction in buffalo milk production in developing countries, it is necessary to increase the buffalo production level to contain fixed costs while also increasing the value of buffalo milk. This latter objective may be pursued only if a market of recognisable, appreciated, and well-differentiated buffalo products will be created. This approach may be faster than a genetic improvement approach as carried out with traditional methods. When the *in vitro* embryo production technique and the transfer will become more efficient and economical, this approach is likely to have become more feasible. In the meantime, however, dairy cattle production will further increase due to the widespread use of instrumental insemination. This technique also allowed to replace the local breeds with crossbred subjects often obtained by using the semen of Holstein or Jersey bulls, with relevant increases in milk production [12]. Conversely, crossbreeding has not been used in the buffalo sector. One of the most productive buffalo breeds where systematic progeny tests are carried out, such as the Italian Mediterranean Buffalo, is not common in developing countries where, for technical-cultural reasons, the technique of mating between buffaloes of different breeds is rarely applied [13].

In 2018, as compared to 1961, there was an increase in the number of buffaloes higher than cattle (Table 2). In particular, the increase in buffalo

Table 5: Values of the Ratio between the Number of Animals Raised and the Quantity of Milk Produced in 2018 Compared to those Recorded in 1961

	number				number		
	buffalo	cow	Difference Buffalo - cow		buffalo	cow	Difference cow-buffalo
Egypt	2,34	2,96	-0,62	Egypt	2,79	5,72	2,93
India	2,23	1,05	1,18	India	8,28	10,26	1,98
Nepal	6,64	1,27	5,37	Nepal	3,94	4,6	0,66
Pakistan	5,79	3,25	2,54	Pakistan	6,68	9,92	3,24
Italy	22,3	-0,602	28,32	Italy	17,65	1,2	-16,45

population has always been higher than in the bovine population in India (+ 1.18), Nepal (+5.37), Pakistan (+ 2.54), and Italy (+ 28.32). Egypt is an exception where livestock growth has been highest (+ 0.62). The percentage increase in buffalo raised in 2018 compared to 1961, depending on the increase in the buffalo population, except Egypt after 2010, and the decrease in cows in Italy (Figure 20) and India. In Italy, the decrease in the dairy cattle population occurred due to cattle genetic improvement and the need to stay within the milk quotas imposed by Europe. A different scenario occurred in India, where the increase in mechanization reduced animals' traction after 1990 (Figure 14), as in India, cattle are used as working animals more than buffaloes.

Despite the increase in the buffalo population, the increase in the amount of milk has always been in favour of cow's milk (Egypt + 2.93; India: + 1.98; Nepal + 0.66; Pakistan + 3.24) except in Italy where buffalo milk increased 16.45 times more than bovine milk (Table 5).

The difference between the increase in bovine as compared with buffalo milk has been particularly evident in Egypt and Pakistan (about 3 times). In Egypt, this difference is partly justified by the decrease in the buffalo population, while in Pakistan, the decrease occurred despite the increase in the buffalo population, which was 2.54 times higher than that of cattle. Although the buffaloes increased 5.37 times more than cattle in Nepal, the difference between the increase in milk production of the two species was similar. In India, the increase in the buffalo population was 1.18 times higher than that of cattle, although cow milk production increased 1.98 times more than in buffaloes.

A decrease in the buffalo population where they are more commonly bred may have adverse effects not

only on the local economy but also on human health. Recent research conducted on the milk of the Italian Mediterranean buffalo [14-16] showed higher amounts of δ -valerobetaine in buffalo than in cow milk. This substance reduces stress and oxidative endothelial inflammation and plays a beneficial dietary role in promoting human health.

CONCLUSIONS

Despite the better adaptation of buffaloes to tropical and subtropical countries, dairy cattle's higher production performance is negatively affecting the consumption of buffalo milk. In order to reverse this trend, the production level of the buffalo should increase to make it more profitable. However, this is difficult to obtain due to technical constraints. Therefore, a marketing effort is needed to make well-differentiated buffalo products with specific and well-received sensory properties following the Italian example of mozzarella cheese. Both goals can be pursued. This is possible because the consumption of dairy products in Asian countries has increased in recent years. The technology for the production of lactose-free mozzarella is already available. In lactose-free mozzarella, thanks to the enzyme lactase addition, lactose is broken down into more simple sugars. For this reason, it will not cause problems for intolerant people.

It should also be emphasized that milk and buffalo meat contain bioactive molecules beneficial for human health in greater quantities than cow's milk.

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