Characteristics of Buffalo Production and Research Systems in Southern Mexico

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Abstract: *Background*: This research aimed to characterize the production units of water buffalo (*Bubalus bubalis*) and review the published scientific literature in southeastern Mexico.

Methods: Between May and June 2020, a questionnaire was created in Google forms, distributed through social networks, and emailed to buffalo breeders. In addition, a review of different scientific databases on the experimental studies developed in Mexico on buffalo was performed.

Results: Data was collected from 8,867 animals from 13 producers located in southeastern Mexico; dual-purpose (milk-meat) is the primary zootechnical purpose (69.24%), and the rest is meat production. The buffalo herd is mainly composed of females (72.09%). Females are used primarily to repopulate the herd and males for meat production. Mortality in adults remained between 2 to 5%. 30.76% of the producers produce milk (495 females) with 5.1 L/d on average. 100% of the producers stated that they transform the milk into dairy products, mainly cheeses and other products. In the case of meat production, 31.97% of the males are fattened based on pastures with a weight range between 400-600 kg at the age of 22 months (range 18-30 months). Between 2012-and 2021, 19 studies related mainly to herd health (63.15%) were registered.

Conclusion: It is concluded that this Mexican species has great productive potential with different areas for improvement. Due to sanitary management and rusticity, mortality is low. It is necessary to develop other lines of research associated with the reproduction, production of milk/meat, health, quality of products, safety, and sustainability of buffalo activity in Mexico.

Keywords: Water buffalo, Productivity, Meat, Milk, Health.

INTRODUCTION

The water buffalo (*Bubalus bubalis*) is a multipurpose animal, long-lived, docile, easy to manage, and capable of being raised economically in varied ecosystems [1]. It was introduced to the American continent at the end of the 19th century, used first for animal traction, later for meat production, and finally for dairy [2].

The production of buffaloes in Mexico is recent compared to other countries in America, intending to take advantage of the lowlands with poor pastures in the states with a tropical and subtropical climate [3-5].

According to Maitret-Collado [5], between 1992 and 1999, just over 3,000 heads were introduced from the United States and Belize, mainly Carabaos or Swamp buffaloes, and later river buffalo from Bufalypso breed, from the island of Guam and Trinidad and Tobago, respectively. The intention was to create an alternative system of livestock production for the production of meat, milk, and work [5].

This work aimed to characterize the buffalo production units in southeastern Mexico and to identify the published research works on the species in the country, which will allow determining some of the areas of opportunity to improve production systems. The characterization of the production units allows knowing the limitations and potentialities of the different aspects of the system: technical, productive, reproductive, and environmental components to develop plans, projects, and public policies for the transfer of technology,

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develop the industry, and improve productivity [6, 7]. Due to the opportunity to produce meat, milk, work, and novelty, the use of this specie as part of the production system offers Mexican livestock and food production a profitable and sustainable alternative [8].

MATERIALS AND METHODS

Survey Application

Between May and June 2020, a specially designed questionnaire was prepared on the Google forms platform (https://forms.gle/XoNfsRAKGve8KRa2A) and was sent to water buffalo producers in southeastern Mexico. The questionnaire was distributed through social networks, by email, and in print, in accordance with Ferreira *et al.* [9]. The questionnaire with 43 questions was designed with four sections: 1) identification of the production unit; 2) herd inventory; 3) technical aspects; and 4) commercial aspects.

Buffalo Research in Mexico

The search period was from 2012 to 2021. The information search was carried out with the following keywords: buffaloes, buffalo, *Bubalus bubalis*, Mexico, productivity, production, diseases, health, artificial insemination, reproduction, welfare, sustainability. Boolean operators (and, or and not) were used to filter or broaden the search results. Databases such as Web of Knowledge, Scopus, CAB Abstracts, and PubMed on the scientific literature published about buffaloes in Mexico on the water buffalo were reviewed. Review articles and meta-analyses published by Mexican researchers on buffalo activity were excluded.

The analysis of the information was carried out in the SPSS program [10] through a descriptive approach in which frequencies and percentages were calculated, taking as reference the number of producers that answered the survey, the total number of animals, and the number of published studies within each category.

RESULTS AND DISCUSSION

Identification of Production Units

The survey was answered by 13 buffalo breeders distributed in 5 states of southeast Mexico. Figure **1** shows that the state of Veracruz had the highest number of production units, followed by Chiapas and finally Tabasco, Oaxaca, and Campeche, with one producer surveyed in each state, respectively. The above is consistent with previous studies that confirm

Figure 1: Distribution and ubication of the surveyed buffalo production units. Source: National Institute of Statistics and Geography (INEGI) [11].

that the state of Veracruz is the state with the most significant number of production units [6, 11].

According to data from the National Institute of Statistics and Geography (INEGI), the states of southeastern Mexico have a warm-humid and semi-warm-subhumid climate, characterized by temperatures above 22°C with temperatures of rain during the year or very abundant in summer [12]. These conditions could be considered ideal for production with the species. Although, it has also been reported that buffalo are currently distributed in 21 states of Mexico on better quality land and various production systems, with a sustained annual growth rate of 18% in the last ten years [13].

Regarding the zootechnical purpose of the production units, 69.24% (n=9) of the producers stated that they are dedicated to dual-purpose production and 30.76% (n=4) exclusively to meat. Dual-purpose systems are defined as those in which milk and meat are produced simultaneously, the females are partially milked, and the residual milk is consumed by the calves. In addition, the feeding is mainly based on grazing [8]. This management is favored by the versatility of the species, in addition to making it ideal for small producers as they have at the same time the possibility of generating income from the sale of weaned animals and/or fattened animals and daily income from the sale of milk, favoring the use of the buffalo in a social context. In the case of meat production systems, they do not have significant differences from the mother-calf systems implemented in grazing cattle [14-16].

Herd Inventory

The 13 producers surveyed concentrate a total of 8,867 buffalo heads. According to data from the Mexican Buffalo Breeders Association (AMEXBU), they are around 45,000 heads in Mexico [13]. Hence, the number of buffalo in this study represents approxi-mately 19.70% of the country's estimated population.

Table **1** shows the numerical and percentage distribution of the buffalo. Females represent a 72.09% (n=6,393), while males represent 27.90% (n=2,474). The females are kept mainly as breeding stock and, once they finish their reproductive life, are used for meat production. In the case of males, 100% of the producers indicated that they are destined for meat production, and 35.7% of the producers consider that their males can be used as breeding stock. The results are similar to those reported in a study in Colombia, in which it was mentioned that the greater number of females is consistent with a sustainable herd from the technical point of view because it guarantees the continuity of production, while the males have a defined duration in the herd [17].

Table 1: Distribution of Buffaloes according their Category

Category	Number	Percentage
Females		
Adult	4.624	72.32
Heifers	829	12.96
Calves	940	14.70
Total	6.393	
Males		
Adults	279	11.27
Steers	1.506	60.87
Calves	689	27.84
Total	2.474	

Technical Aspects

Reproduction

All production units use natural mating (100%/ n=13), a low proportion artificial insemination (AI) using natural heat (23.07%/ n=3). There are still many limitations to the widespread use of AI in natural heat; the difficulty of identifying buffaloes in estrus and the knowledge about the exact time to perform the AI should be mentioned [18]. Additionally, the efficiency to detect estrus under field conditions is reduced, only 41% of the females are detected, and the insemination at the correct time occurs only in 21% [19]. Some producer uses vasectomized males to detect estrus, which increases the breeding success of production units (Figure **2**). In this regard, it has been reported that vasectomized bulls increased the number of spontaneous estrus per buffalo (69 vs. 92%; $p<0.05$) and decreased the incidence of anestrus (31.1 vs. 20.8%; $p<0.05$) compared to female buffaloes without vasectomized bulls [18]. In recent years, fixed-time artificial insemination (FTAI) has gained attention, but none of the participants of this survey use it. Although it is used, it is not widespread in the country. Modern reproductive technologies like estrus synchronization along FTAI should be practiced for genetic improvement and control of the venereal disease.

Figure 2: Vasectomized male for estrus detection. Males are used in artificial insemination programs for estrus detection. In general, two 20–30-month-old males are used for a batch of 60-70 buffaloes. Photography courtesy: Armando Morales Lagunes.

On the other hand, in the total of the surveyed production units, 4,225 calves were born. It has been observed a seasonal effect; it was found that the majority of calves are born between August and December. In Colombia, 65.7 % of births occur in the second half of the year, with a peak in October (13.3%) [20]. In another study in Cuba, it was recorded that 95.4% of births were distributed between June and October [21]. More recently, in Panama, it was found that deliveries are concentrated in the third quarter of the year (July to September), with 80.8 % and 69.2% occurring between August and September [22]. These results demonstrate reproductive seasonality in buffalo previously reported, with fertile estrus between September and December. It is essential to point out that since the gestation length is 305-315 days, the service period (calving/conception) in this species should not exceed sixty days to obtain twelve months of calving intervals and avoid economic losses [23]. In other countries such as Italy, where it is mandatory to have buffalo milk all year round to meet the demands of the markets, deseasonalization has been developed as an alternative for reproductive management [24].

On the other hand, 98.22% of the calves (n=4,150) were weaned, weighing an average of 226.66 kg (range of 200-280 kg) between 6 and 9 months of age. Regarding mortality, these results were different than those reported in Panama where 0 % mortality was observed in calves from calving to weaning [22] while weaning weights are similar to those reported by López *et al*. [25] in dual-purpose and meat production systems.

Health

Some authors mention that mortality in calves should not exceed 5% [26]. In this work, a mortality rate lower than 2% was found, which can be attributed to the fact that in none of the production units, the calves are separated early from the mothers, which favors the transfer of passive immunity and promotes maternal care of the calves [14].

On the other hand, 100% (n=13) of the producers apply preventive treatments against bacterial diseases in calves such as blackleg, malignant edema, infectious necrotic hepatitis, enterotoxemia, and respiratory infections associated with *Clostridium* sp, *Pasteurella* sp, *Haemophilus Omni*. In relation to antiparasitic treatments, based on the fact that 46.15% (n=6) of the producers observed that parasitosis occur in calves, and 38.46% (n=5), 15.38% (n=2), 23.07% (n=3), 7.69% (n=1), and 7.69% (n=1) of the producers deworm once a year, twice, three, four and up 5 times a year, respectively. Finally, one producer stated that he does not apply dewormer. It is important to note from a Mexican study that buffalo calves present up to 7.79 more times of being parasitized compared to adult buffaloes [27]. It would therefore be necessary to implement more efficient health programs for calves at an early age. On the other hand, 38.46% (n=5) of the producers indicated that respiratory diseases also occur, and 23.07% (n=3) indicated that no diseases had been found in the production units.

In the case of adult animals, the percentage of mortality found was in the range of 2-5%. The majority of diseases are reported in females; 38.46% (n=5) of the producers indicated that septicemia is one of the main diseases, followed by respiratory diseases with 30.76% (n=4), other conditions such as mastitis, retained placenta, parasites, Brucellosis and tuberculosis represent 30.76% (n=4). Two producers (15.38%) stated that there were no diseases. In the case of males, 46.15% (n=6) of the producers indicated that they did not find diseases, 23.07% (n=3) had septicemia, 23.07% with respiratory conditions (n=3). Likewise, 23.07% (n=3) corresponds to other diseases such as parasitosis, Brucellosis, and tuberculosis. The low incidence of diseases can be associated with the zootechnical purpose of male buffaloes, as they are mainly sent for meat production.

Regarding sanitary management in adult animals, 92.30% of producers (n=12) apply bacterins to adult animals similar to those indicated in calves, 23.07% (n=3) stated that they also use bacterins against

Brucellosis, and only one producer said they do not apply any preventive treatment to adult animals. A producer applies the bovine paralytic rabies vaccine. Regarding deworming, 46.15% (n=6) of the producers deworm adult animals once a year, and 38.46% (n=5) do it twice a year. However, one of the producers mentioned that deworms once every three years, and one does not deworm the animals.

The water buffalo is known for its rusticity and great adaptability to different topographies, soils, and climatic factors. It is believed that it does not present diseases as in cattle. However, they can also be affected by various infectious diseases that significantly impact their productive performance [28], in addition to the transfer of conditions in production systems where animals of different species coexist. It is very important to remember that the water buffalo is a bovine and can share diseases that affect other bovines, such as leptospirosis, neosporosis, Brucellosis, tuberculosis, and bovine viral diarrhea (BVD), fasciolosis, [4, 29, 30] that it is common in cattle. Health studies in water buffalo are relevant to solving animal health problems, establishing control measures, and avoiding zoonoses; since clinical signs are not evident in buffalo, the various diseases could be under-quantified in the production units.

Characterization of the Productive Units

Regarding the infrastructure, 92.30% (n=12) of the producers have work pens, scales, work chutes, and loading and unloading ramps. At the same time, the paddocks are delimited by electric fences and natural fences. The main characteristics of the production systems indicated that 100% (n=13) of the producers keep the animals in continuous (Figure **3A**, **B**) and rotational (Figure **3C**, **D**) grazing systems, of which 53.84% (n=7) raise animals on native grasses, 38.46 % (n=5) use improved pastures and 7.7 % (n=1) in mixed systems with supplementation under dry season. One of the producers indicated that he implements Voisin Rotational Grazing (VRG) (Figures **3E-F**). VRG can be defined as a rotational method for managing the soil-plant-animal complex through direct grazing and well-planned pasture rotation. In addition, VRG delivers high animal productivity while improving ecosystem services [31].

The main nutritional advantage of the buffalo lies in the fact that it has greater efficiency in the use of fibrous material. For many decades, buffalo were fed a fibrous diet, low in protein and energy, predominantly from native grasses; therefore, they developed adaptations in the digestive system, which allowed increasing the efficiency of the use of this fibrous material [32]. In according of different studies, buffaloes can present weight gains of 0.30 kg/day in monoculture systems [33], between 0.37 [34] and 0.70 kg/day [35] in pasture rotation systems, and around 1.0 kg/d or more in silvopastoral systems with natural shades [33] and intensive systems [36]. The above should be considered by producers to make production systems more efficient and guarantee appropriate weight gains according to the meat market.

Regarding the characteristics of the production systems that favor thermoregulation in the buffalo. It is observed that 92.90% (n=12) of the production units have natural shades and stagnant water, 64.3% (n=8) with puddles of mud, 21.4% with artificial pools (n=3), 14.3% with natural shadows (n=2), 7.1% (n=1) puddles per season, generally in the rainy season and 7.1 with jagueyes (small lagoons) (n=1) (Figure **4A-D**).

A general idea in buffalo production systems is that ponds and water are required to favor its thermoregulation due to its dark-colored, thick skin and lower density of sweat glands than cattle [37, 38]. In addition, it is believed that the water or mud with which buffaloes cover their bodies is also a mechanism against ectoparasites [39]. However, it is important to consider that buffaloes that graze freely on flooded land are more susceptible to endoparasites (fasciolosis and schistosomiasis), leptospirosis, Brucellosis, among other diseases such as mastitis, causing an economic impact due to low production, high mortality, and a threat to public health [28, 40]. Finally, it is important to point out that buffalo can be productively efficient without the need to express their thermoregulatory behavior, as long as this natural behavior is substituted with the provision of natural or artificial shade and in an environment very close to the thermoneutral zone, as has been reported previously [38, 41].

Commercial Aspects

Milk and Meat Production

It was found that four farmers (30.76%) milk 495 females, which represents 10.70% of the population of adult females surveyed. 80% (n=3) of the milk them using machine (Figure **5A-C**) and 20% (n=1) manually. Unlike the cows, the maternal instinct plus the presence of the calf continues to be very important for milk ejection in dairy buffaloes [42], evidenced by the observation that 80% (n=3) of the producers mainly

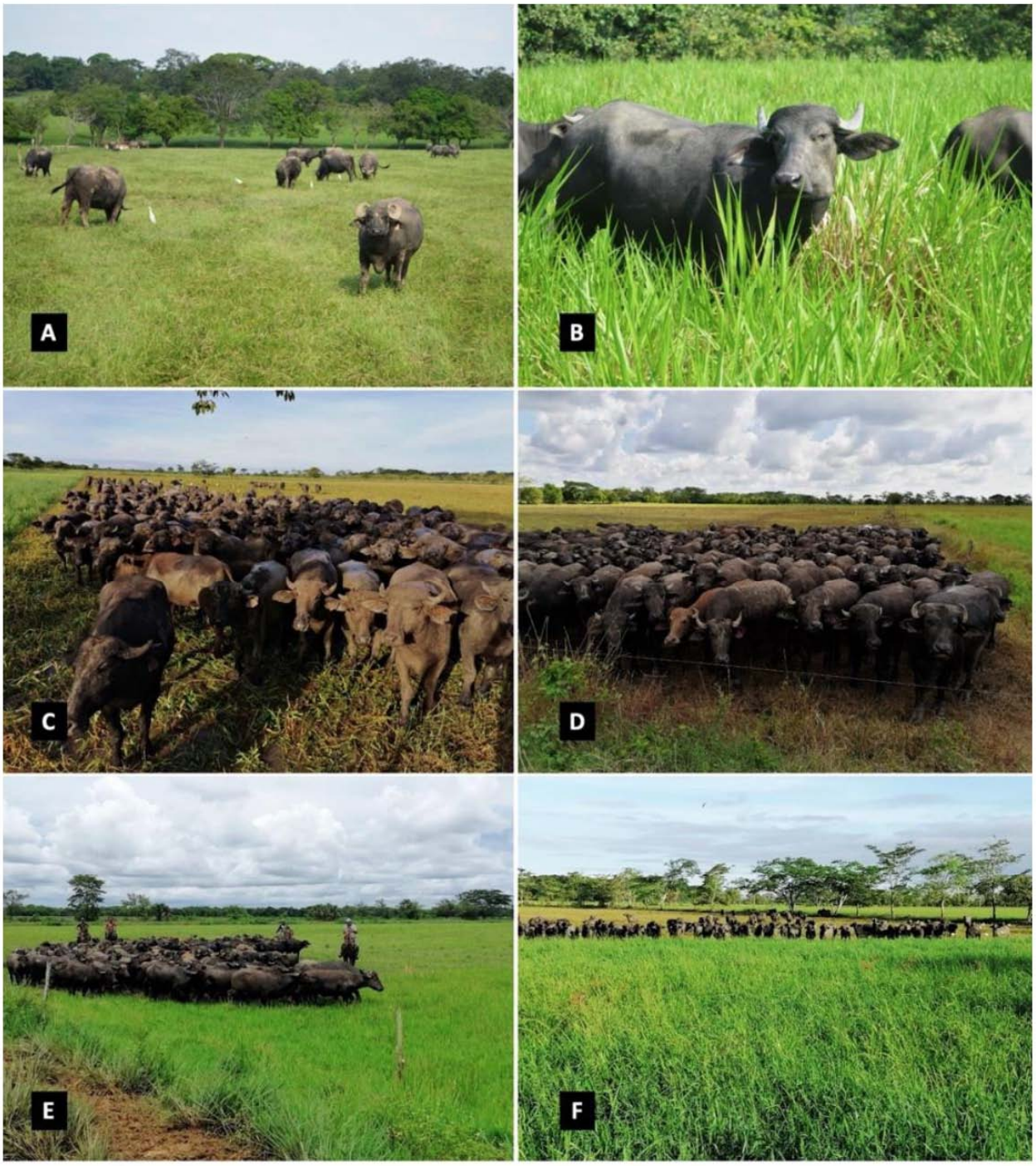

Figure 3: Buffalo grazing systems in Mexico. **A**) and **B**). Buffaloes in continuous grazing; **C**) and **D**) Buffalo in rotational grazing systems; **E**) and **F**) Voisin Rotational Grazing (VRG). Photos courtesy: **A**) and **B**) Luis Alberto de la Cruz Cruz, **C**) Armando Morales Lagunes, **D**), **E**) and **F**) Jorge Ayala Filigrana.

use the calf as a stimulus, 60% (n=2) of the producers also use oxytocin and 20% (n=1) use feeding during milking. It has also been reported that sometimes the mother stops lactation when the calf dies. Therefore, it is necessary to introduce strategies to promote milk ejection, such as the transfer of stimuli, early habituation or before calving, and personnel training during routine milking [14, 43]. The consideration of good practices in milking increases personnel safety and decreases the incidence of mastitis [44].

The average milk production is 5.1 liters/day /animal (range 4 to 6 liters/animal). The milk price is around $9.1 Mexican pesos (USD 0.46). According to Ahmad *et al.* [45], the physicochemical composition of buffalo milk has a higher content of fat, total solids, proteins,

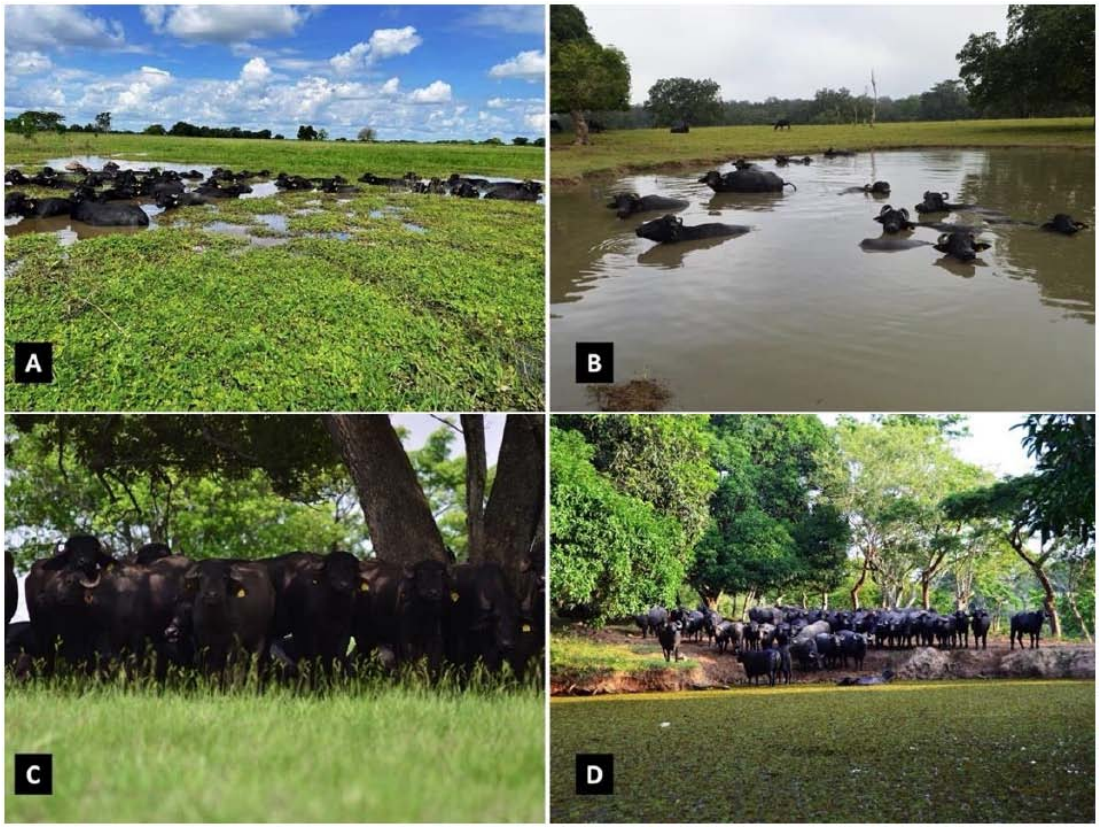

Figure 4: Thermoregulation in buffaloes. A) y **B**) Availability of water for wallowing in production systems. **C**) Presence of natural shadows; **D**) Presence of natural shadows and water. Photos courtesy: **A**) Miguel Ángel Lendechy; **B**) Luis Alberto de la Cruz Cruz, **C**) y **D**) Eduardo Maitret Cors.

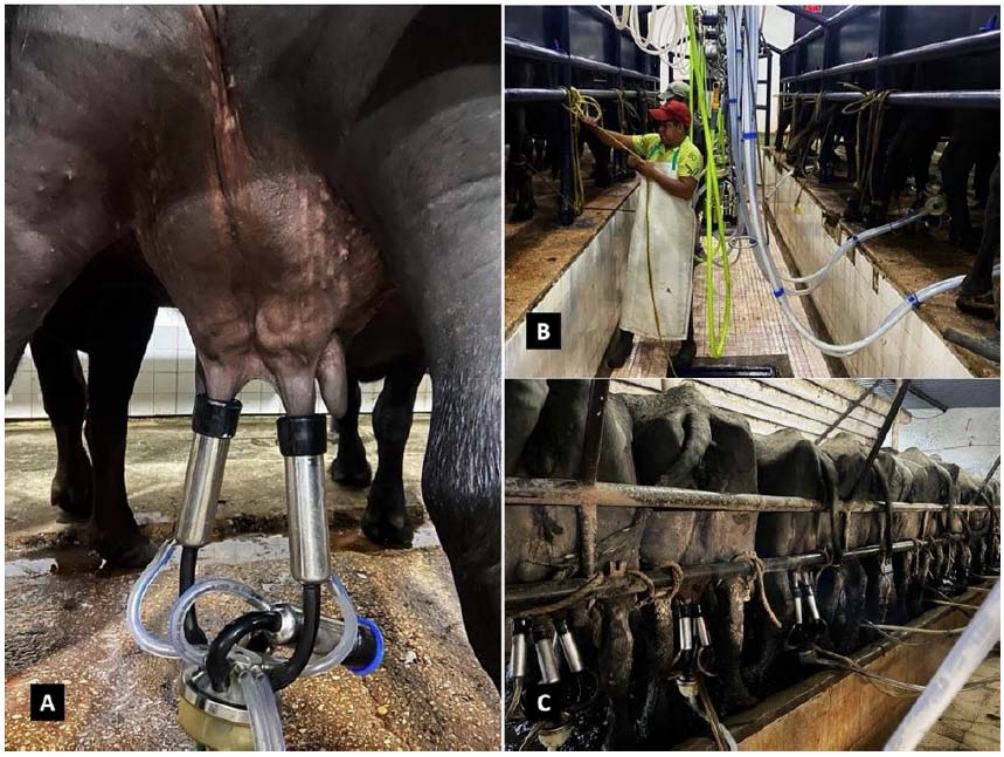

Figure 5: Mechanical milking in dairy buffaloes. A) and **B**) In dual-purpose systems in Mexico, 2 quarters of the udder are milked, usually the hind quarters. **C**) In other systems, all four quarters are milked. Milk in the udder after of milking is destined for calves in dual-purpose systems. Photos courtesy: **A**) and **B**) Eduardo Maitret Cors and **C**) Miguel Ángel Lendechy.

caseins, lactose, and ashes, which are the essential constituents from the point of view of an economic point of view compared to cattle [45, 46]. Also, the higher levels of fat and protein in buffalo milk make it a cheaper alternative to cow's milk to produce casein, caseinates, whey protein concentrates, and a wide range of high-fat dairy products [47].

A hundred percent (n=4) of the milk producers stated that they transform milk into dairy products. 100% of the producers make cheese (n=4), but ice cream, butter, yogurt, and dulce de leche with 25% each. 80% (n=3) of the producers sell their products locally, but also with intermediaries in 40% (n=2), restaurants and hotels with 20% (n=1) and own points of sale with 20% (n=1). One producer sells refrigerated milk.

Of the total number of males surveyed (n=2,474), 31.97% are used for meat production, and the animals are sent to the slaughterhouses with around 489 kg on average (range 400-600 kg) with an age of 22 months (range 18-30 months of age) (Figure **6**). This coincides with reports in Brazil where buffaloes are destined for meat production with a weight between 430-480 kg at 24 months of age. In the case of Argentina, the animals can reach 480 kg at 24 months of age and 550 kg at 27-30 months of age [48, 49]. In general, animals can have daily weight gain between 500-1,000 g/day depending on the production system, and carcass yields between 52-54% [48, 49]. In the year in which the survey was conducted (2020), the average price of live buffalo was around 32 Mexican pesos/Kg (USD 1.61) and the cost of the carcass was $65/Kg Mexican pesos (USD 3.26).

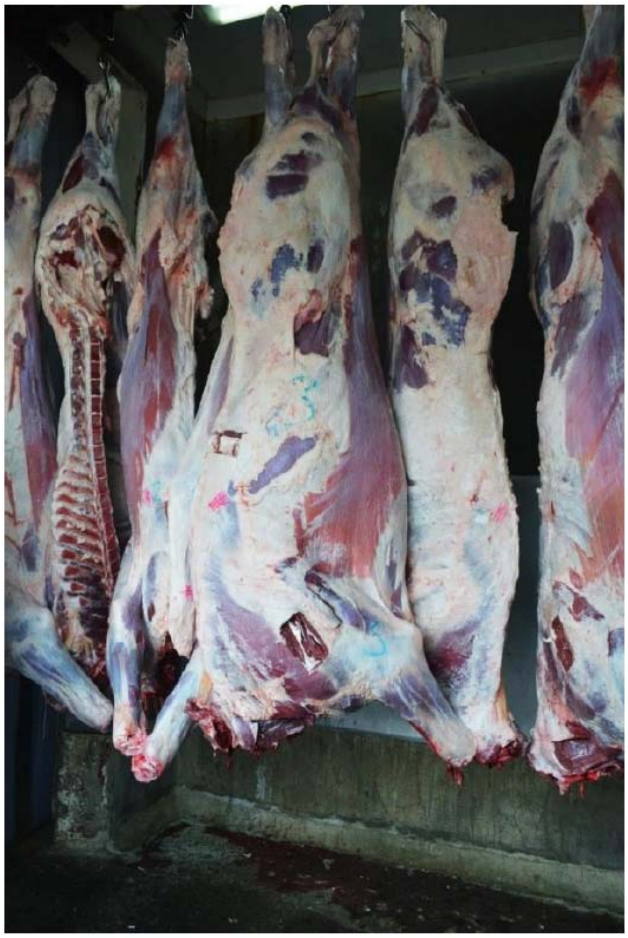

Figure 6: Carcasses of buffaloes fed in grazing systems. Young buffalo carcasses can have yields of approximately 52-54 %. Photos courtesy: René Rodríguez Florentino.

Water buffalo meat has been highly appreciated due to its nutritional characteristics (low cholesterol content, lower lipids than beef and pork, higher proportion of unsaturated/saturated fatty acids, and higher iron content than beef, pork, and rabbit) [50-52]. However, one of the main drawbacks of meat marketing is that buffalo carcasses in most American countries are introduced into the meat circuit as "beef" without differentiation of the species; sometimes, these carcasses are classified under the same prevailing system for cattle, despite being different species [53]. Usually, they are paid at a lower price than beef, which is considered unfair, given their high nutritional value [54]. Others argue for this differential payment the erroneous concept of lower buffalo carcass yield. However, the yield of buffalo carcass is caused by the high weight of skin, head, legs, and others [55], so it is necessary to build the conditions for a good market for buffalo meat.

Consistent with the vocation of breeders, there is a more significant population of young buffalo for meat production; it has been reported that meat from young buffalo (~ 2 years old) and adequately fed may have better physicochemical and sensory characteristics, even it can compare favorably with meat from zebu cattle [56-58], which will allow buffalo meat produced in Mexico to meet market expectations in terms of both national and international quality. A weakness of the production system previously reported in other countries is the practice of sending females and males to slaughter after fulfilling their productive life, since they can present various alterations in the quality of the meat, making it unacceptable to consumers, generating an idea widespread belief that buffalo meat is extremely tough and dark [59-61].

One of the actions of breeders is to emphasize having quality animals with management to maintain

meat quality considering the age at slaughter and the conditions of rearing and feeding [62, 63]. In addition, the effect on the meat of some post-mortem management strategies should be investigated to favor meat tenderness, such as electrical stimulation of the carcasses [64], moist [65] and dry maturation of the meat [66], while the use of antioxidants such as ammonium hydroxide (NH4OH) [60] and vitamin C [67] could be used to enhance meat color.

On the other hand, an advantage of products derived from buffalo activity is that they are increasingly sought after by people looking for healthier food options. Previous studies have indicated that buffalo milk might be more suitable for human health than cow's milk due to its A2 classification [68] and because β-lactoglobulin is less allergenic than cow's milk proteins since they do not increase IgE sensitization, as well as lymphocyte proliferation, which causes a lower incidence of allergies in consumers [69].

In addition to the above, previous studies have indicated that a pasture-based diet improves the concentration of CLA (conjugated linoleic acid)

Table 2: Characteristics of the Published Research about Buffaloes in Mexico

Investigation area	Year	Aims	State	Number of animals evaluated	Reference
Health	2012	Seroprevalence of Brucellosis	Veracruz	99 young and adult buffaloes	[4]
Health	2014	Seroprevalence of *Toxoplasma gondii*	Veracruz	339 buffaloes of different sex and age	[74]
Health	2016	Molecular and serological detection of *Babesia Bovis and Babesia bigemina* infections	Veracruz	154 adult buffaloes	[75]
Health	2017	Seroepidemiology of infection with *Neospora caninum*, Leptospira and bovine herpesvirus type 1	Veracruz	144 buffaloes of different sex and age	[30]
Health	2017	Identification of gastrointestinal parasites	Tabasco	251 adult and 132 young buffaloes	[27]
Health	2017	Determination of hematologic values	Veracruz y Tabasco	126 buffaloes of different age	[76]
Health	2018	Seroepidemiology of infection with bovine herpesvirus type 1	Veracruz	368 adult buffaloes	[77]
Health	2018	Presence of ticks *Amblyomma mixtum*	Veracruz y Oaxaca	30 adult buffaloes	[3]
Health	2019	Identification of nematophagous fungi from feces against *Haemonchus contortus*	Veracruz	25 buffaloes from 9 months to 2.5 years	[78]
Health	2020	Identification of infection with *Anaplasma marginale* in buffaloes with ectoparasites (*Haematopinus tuberculatus*)	Veracruz	42 buffaloes of different age	[79]
Health	2021	Seroprevalence and risk factors associated with *Neospora caninum*	Veracruz	543 buffaloes of different age	[7]
Health	2021	Determine the frequency of *Neospora caninum*	Veracruz	138 buffaloes of different age	[80]
Welfare	2020	Determination of physiological responses at weaning	Veracruz	40 buffalo calves	[16]
Welfare	2021	Determination of physiological and behavioral responses at weaning	Veracruz	40 buffalo calves	[15]
Sustainability	2018	Analyze indicators associated with the cultural management of buffalo production	Veracruz	3,036 buffaloes of different ages	[11]
Sustainability	2018	Evaluate of *In-vitro* fermentation variables of a cellulolytic bacteria	Guerrero	1 female adult	[81]
Sustainability	2019	Evaluate of production of *in vitro* gases and ruminal fermentation	Guerrero	1 female adult	[82]
Reproduction	2020	Evaluate of estrus synchronization with different hormonal protocols	Veracruz	29 female adults	[83]
Milk quality	2020	Evaluate of production, physicochemical characteristics and sensory profile of buffalo milk	Veracruz	24 dairy buffaloes	[84]

isomers, which has beneficial effects on human health, as well as immunomodulatory and anticancer activity [34]. This has been previously reported in buffalo meat [70] and milk [71]. Finally, the conditions of raising and feeding based on natural pastures are close to the standards and practices of soil and nutrient management required by the protocols for ecological and organic certification, which could generate added value to the products of water buffalo [72, 73].

Buffalo Research in Mexico

A total of 19 scientific papers were published between 2012 and 2021 (Table **2**), it belongs to health 63.15% (n=12), 15.78% (n=3) on sustainability, 10.52% (n=2) on animal welfare, 5.26% (n=1) on reproduction and 5.26% (n=1) on milk quality. Of these studies, 84.21% (n=11) was carried out in Veracruz, which coincides with the state in which the largest number of production units is found, 21.04% (n=2) was carried out in Guerrero and 10.52 % (n=2) was carried out in Tabasco and 10.52% (n=2) in Oaxaca.

CONCLUSIONS

The water buffalo in Mexico has a high productive potential; since its introduction to Mexico, it has been managed to adapt to tropical conditions in swampy lands. The primary zootechnical purpose of the water buffalo has been concentrated in meat and milk production. However, it is necessary to establish more efficient market channels to diversify consumption. On the other hand, the research published in scientific journals is limited, so it is essential to develop different lines of study associated with improving different areas at a productive level and related to quality, safety, and sustainability. Thus, with modern improvement aids and the application of the practical systems developed for cattle with the corresponding adjustments for buffalo, they will be able to put Mexico in the leadership of buffalo, American, and world production.

APPROVAL FOR PUBLICATION

The authors declare that the producers agree to publish the information derived from the survey, as well as the photographic material.

AVAILABILITY OF DATA AND MATERIAL

The data will be available on reasonable requests from the corresponding author.

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CONFLICT OF INTEREST

The authors declare that there is no conflicting interest with regard to the publication of this manuscript.

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