Description of Four Dual-Purpose River Buffalo (Bubalis bubalis) Production Systems in Tropical Wetlands of Mexico. Part 2: Sanitary Management, Milking, Zootechnical and Economic Indicators

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Abstract: The aim is to elucidate other key aspects of these dual-purpose systems in wetland areas, including labor, markets, the conditions of facilities, machinery and equipment indices, and zootechnical indicators. The health management values determined for production units (PU) PU2, 3, and 4 were similar (50%) but higher at PU1 (75%). Three scheduled milkings once a day (1x), but PU3 performed it twice a day (2x). Most workers are permanent, but PU1 and PU2 hire temporary laborers. The average workday was 7.69 ± 2.84 hours/animal unit at a mean wage of $11.43 ± $1.27. Unit prices per kg of meat from fattening animals and liter of milk were $1.83 ± $0.03 and $0.51 ± $0.08, respectively. Production variables showed an average calving interval of 371.25 ± 7.50 days, a mean parturition index of 89% ± 1%, and mean mortality of 1.8% ± 0.5% and 0.6% ± 0.8% for young and adult animals, respectively. Milk production per lactation was 1240 ± 211.66 liters. The mean daily production for sale was 5.17 ± 0.88 liters. Individual calves consumed 2.13 ± 0.63 liters of milk per day on average. Mean productive life was 17 ± 2.45 years. Average scores on the facilities conditions and machinery and equipment indices were 68% ± 14% and 57% ± 26%, respectively.

Keywords: Water buffalo, production system, tropical wetlands, zootechnical and economic indicators.

INTRODUCTION

This article complements an earlier text entitled “Description of four dual-purpose river buffalo farms in Mexico’s tropical wetlands. Part 1: social aspects, herd distribution, feeding, reproduction, and genetic management” [1]. Our objective in this part is to complete the characterization of these DPBPS by focusing on other key dimensions: health and sanitary management, milking, labor, market prices, zootechnical indicators, facilities, and machinery and equipment.

Two activities often blamed for environmental deterioration are agriculture and livestock-raising, so new strategies are being devised to achieve multiple objectives, especially producing food of the quality and in the quantities that humanity demands in the short term using the fewest resources possible during minimizing environmental impact [1, 2]. Adopting sustainable production models and efficient technological practices and evaluating elements that interact symbiotically with the environment have been proposed for their potential benefits in configuring or redesigning agricultural production systems, especially in relation to direct interaction with ecosystems as occurs DPBPS in Mexico’s tropical wetlands [3-6].

The river buffalo (*Bubalus bubalis*) is a species well-adapted to humid tropical environments due to key anatomical, physiological, and behavioral attributes that provide efficiency and resistance in these production systems. This species allows sustainable exploitation of natural resources [7] with low or null dependence on external inputs, a capacity for efficient production, and a fundamental principle of agroecology [5, 8].

Despite the recent expansion of river buffalo production in Mexico’s tropical wetlands, few studies have characterized and evaluated DPBPS in detail, so

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Table 1: Qualitative and Quantitative Variables Analyzed

Dimension	Variable	Dimension	Variable
Sanitary management	Tick baths (frequency)	Facilities	Warehouse
	Clostridium Vaccination (frequency)		Corrals
	Brucella Vaccination (frequency)		Roof or cellar
	De-worming (frequency)		Gallery
Milking management	Milking system		Feeding troughs
	Milkings per day		Milking parlor
	Stimulus used for milk ejection		Handling chute
Labor	Types of workers	Zootechnical indicators	Age at first service (months)
	Permanent day workers		Weight at first service (kg)
	Temporary workdays		Age at first calving (months)
	Wages paid per day		Birth weight, males (kg)
	Daily wage		Birth weight, females (kg)
	Days/AU		Weaning days (days)
Market prices	Buffalo cow (all prices in USD)		Male weaning weight (kg)
	Pregnant buffalo heifer		Female weaning weight (kg)
	Buffalo heifer		Weight of males at 1 year (kg)
	Female buffalo calves (heads)		Weight of females per year (kg)
	Bulls		Days of lactation
	Buffalo steers		Daily milk production (liters)
	Male buffalo calves		Milk production per lactation (liters)
	Price of milk per liter		Milk destined for calves (liters)
	Per kg price of live animal		Milk for sale (%)
Machinery and equipment	Agricultural tractor 1		Milk for buffalo calves (%)
	Agricultural tractor 2		Parturition rate (%)
	Disc harrow		Mortality in adult animals
	Plow		Mortality in young animals
	Trailer		Productive life (years)
	Farm grader		Days open
	Cultivator		Cull rate, buffalo cows (%)
	Thresher		Udder diseases (%)
	Harvester		Leg and hoof diseases (%)
	Weigher		Calving interval (CI)
	Cryogenic chamber		
	Irrigation equipment		
	Baler		
	Milking equipment		
	Feed mixer		
	Mill		
	Power plant		
	Cooling tank		
	Machinery and processing equipment		
	Electric fencing		
	Automobile		
	Pick-up truck		
	Truck		

Table 2: Labor Force used in DPBPS

PU	Type of labor	Permanent day labor	Temporary workdays	Wages per year	Daily wage (USD)	Wages/AU
1	Temporary / permanent	5634	2400	8034	$ 11.95	11.17
2	Temporary / permanent	313	90	403	$ 10.39	4.21
3	Permanent	4695	0	4695	$ 10.39	7.92
4	Permanent	3130	0	3130	$ 12.99	7.48
	Average	3443	622.5	4065.5	$ 11.43	7.69
	SD	2328.29	1185.76	3185.09	1.27	2.84

it is important to gather primary information on diverse components of these systems in these regions. The variables and indicators examined may provide reference values for future studies of DPBPS to identify areas of opportunity and potentially beneficial reconfigurations that could be applied in countries with similar conditions.

MATERIALS AND METHODS

This is a retrospective analysis with data from 2019 that characterize four DPBPS in the study area. The methodological strategy included six steps, described in Part 1. For part 2, we defined 70 qualitative and quantitative variables (Table **1**) and indices to score health conditions, facilities, and machinery and equipment. The study is framed in the reproductive management index proposed in Part 1, "Description of four dual-purpose river buffalo farms…" [1].

Workers

Two PUs hire only permanent staff; the others also use temporary laborers. Our data contrast to those in Arroniz [9], who reported family labor predominantly 43 % in dual-purpose bovine systems, probably due to the smaller scale of the producers surveyed compared to the four PU analyzed herein. On average, we found 4,065.5 ± 3,185.03 workdays/year. PU1 had the highest number at 11.17/AU, possibly reflecting the milking methods used (mixed and manual), more frequent health management activities, and continuous improvements of pastures. PU2 required fewer than half that amount of wages at just 4.2 wages/AU, the lowest value found. The average was 7.69 ± 2.84 wages/animal unit (AU). The average labor cost was $11.43 ± $1.27. The highest value was at PU1, the lowest at PU2 and 3 (Table **2**). The average daily wage was higher than that reported by Martínez-Castro [10], which presented $5.38-$6.15 values. This difference could be due to regional and/or seasonal factors, such as the dates on which field data were collected. Permanent workers are utilized mainly for routine with the animals, while temporary laborers are more often employed in rehabilitating pastures, depending on the growth of grasses, maintenance tasks, and herd rotation according to established programs. Significantly, the owners of these PUs continuously supervise and participate in activities necessary for the good functioning of their systems, so it is necessary to assign a value to their wages when evaluating production activities.

The study detected that the owners of all four PUs are dedicated to their operations and that this could raise their profitability, aided by tight controls and high management capacity. Another common feature of these PUs is that producers perform various activities to obtain additional economic income [9, 11]. Analyses verified that the time producers spend with their herds is closely related to levels of productivity, efficiency, and profitability [12].

Health Management

In the area of health management, only PU2 routinely gave young animals tick baths but were not performed with adults at any PU (Table **3**). The low frequency of this health measure could reflect the fact that the buffalo's thick hide and characteristic behaviors of submerging in water and wallowing in swamps [13-17] reduce insects' ability to adhere its hypostomes to their skin. However, it is important to note that Obregón's study [18] showed that, unlike adults, buffalo calves could suffer tick infestations, so it may be advisable to give young animals regular tick baths.

Concerning the application of vaccines and bacterins, all four ranchers protected their herds from *Clostridium sp,* but only two vaccinated against

Table 3: Health Management on the DPBPS

PU	Tick baths frequency		Vaccination (*Clostridium*) frequency		Vaccination (*Brucella*) frequency		De-worming frequency		Health management index
	< 1 year	> 1 year	< 1 year	> 1 year	< 1 year	> 1 year	< 1 year	> 1 year	
1	0	0	1	1	2	1	6	6	75%
2	1	0	2	2	0	0	2	0	50%
3	0	0	1	1	2	1	0	0	50%
4	0	0	0	0	1	1	3	2	50%
								Average	56%
								SD	13%

PU: production unit; **SD**: standard deviation.

Brucella abortus. Three PUs did internal de-worming on all animals at least once a year. The average health management index was 56% ± 13% (Table **3**).

Although the river buffalo has a great capacity for environmental adaptation, we must remember that they are biological beings. While they may rarely show signs of disease, they can carry and transmit illnesses that could affect other cattle species [19, 20]. Before emitting recommendations in this regard, it is important to conduct diagnostic protocols to identify health and sanitary conditions by region and, where necessary, attend to affected species through zoosanitary campaigns as a control measure to prevent propagation [21]. Note that all four PUs test for *Brucella*. When positive cases are found, the sick animals are disposed of, and the pertinent authorities are informed.

Milking Management

Regarding milking management, we found that PU1 uses mixed techniques (manual and mechanical) to ensure adequate supplies, depending on the ages of calves. Dams with calves with correct development (weight, body condition) are channeled to mechanical milking two months after parturition, but for the others, manual milking continues. PU2 does only manual milking, while PU3 and PU4 use exclusively mechanical equipment (Table **4**). These three PUs employ the same milking system regardless of the age and condition of calves. This finding is similar to that of Granados-Rivera *et al*. [22], who found a high utilization of mechanical milking, but differs from those of two authors who observed that the predominant practice of DPBPS is manual [11, 23]. When working with buffalo species, it is necessary to consider behavioral, anatomical, and physiological features (capacity of the cistern in the udder, conical teats, narrow sphincter canals, rapid formation of keratin plugs) to establish adequate milking routines since dams are much more susceptible to stress factors during milking than bovines [19, 24-28] (Figure **1**).

Three PUs extract milk from the dams' mammary gland once a day in relation to daily milking frequency. Only PU3 did milking twice a day, perhaps reflecting greater intensification and prioritization of milk than in the other PUs. While the greater number of milkings may increase total milk production [30], a disadvantage could be prolonging the period for developing calves for sale. Quiroga [31], however, reported that the increase in milking frequency from once to twice a day in lactating Murrah buffaloes in the final third of lactation could increase milk production without affecting the weight of calves at weaning, as long as nutrition is adjusted accordingly. Milking equipment tends to be similar to that used with conventional bovines, but the tubular structure in milking parlors is usually broader to accommodate the buffaloes' greater body width [21].

All four PUs use oxytocin to promote milk ejection, especially with mechanical milking, but PU1 and PU2 also apply sensory stimuli by presenting the calf to stimulate ejection. PU3 complements this stimulus with balanced feed during milking as a routine incentive (Table **4**). The calf's presence is important for milk ejection because, as mentioned above, the female buffalo stores only 5% of her milk in the cistern. The rest is in the alveolar portion [29, 32]. Alveolar milk only becomes available when it is ejected actively by contractions of the myoepithelial cells in response to a calf's somatosensory stimulation [25, 26].

Market Prices

Regarding estimates of market values, buffalo cows can reach a price (all figures in USD) of $1,168.83 ±

Figure 1: Anatomical differences between the udders of female buffaloes and dairy cows.

A. Lateral view of a buffalo dam's udder. **B**. Lateral view of the cow's udder. **C**. Importance of the buffalo calf in routine milking operations. In Italy, female buffaloes in intensive systems have an average lactation of 2,462 kg with a duration of 270 days. In contrast, Holstein cows can produce up to 9,690 kg in lactations of 305 days. Female buffaloes have less well-developed mammary tissue but can produce milk with better compositional characteristics than that Holstein cows. They are also less susceptible to suffering mastitis due to certain anatomical and physiological features of the udder. The buffalo calf is important for milk ejection since over 95% of the milk produced is in the alveolar fraction, so active myoepithelial contractions derived from oxytocin are fundamental for ejection [27-29].

Table 4: Milking Management

PU	Milking system	Milkings per day	Type of stimulus used for milk ejection
1	Manual/mechanical	1	Buffalo calf/oxytocin
2	Manual	1	Buffalo calf/oxytocin
3	Mechanical	2	Oxytocin/balanced feed
4	Mechanical	1	Oxytocin

PU: production unit.

$108.14.67, pregnant heifers, $987.01 ± $59.98, heifers, $896.10 ± $88.72, female calves, $766.23 ± $107.09, bulls, $1,350.65 ± $59.98, steers, $681.82 ± $23.76, and male calves, $478.05 ± $57.89 (Table **5**). We would emphasize that females are sold as breeding animals, so their price is not calculated in kilograms. Instead, they receive added value depending on their genetic load, specifically for projections of their potential for milk production. Prices for male steers and calves are based on the weight in kilograms when sold, but bulls are evaluated as breeding animals using criteria similar to those applied to females.

For the prices of a kg of meat and liter of milk, we found values of $1.83 ± $0.03 and $0.51 ± $0.08, respectively (Table **5**). When visiting local sources, we verified that buffalo milk costs more than cow's milk ($0.51 *vs*. $0.36) because it is sold to local processors who have found that it gives higher yields when converted into dairy products and derivatives. This contrasts with sales of fattening animals, as local intermediaries pay less for buffaloes, perhaps because buffalo carcasses have lower yields due to the greater weight of their hide and bones compared to bovines [33]. The latter can go for prices as high as $2.02/kg of

Table 5: Market Prices of Animals and Milk*

PU	Buffalo cow (USD)	Pregnant heifer (USD)	Heifer (USD)	Female calves (USD)	Bulls (USD)	Steers (USD)	Male calves (USD)	Liter of milk (USD)	Price per kg of live animal (USD)
1	$ 1,298.70	$ 935.06	$ 883.12	$ 883.12	$ 1,402.60	$ 670.13	$ 492.21	$ 0.44	$ 1.82
2	$ 1,038.96	$ 935.06	$ 779.22	$ 675.32	$ 1,402.60	$ 696.10	$ 509.09	$ 0.62	$ 1.82
3	$ 1,194.81	$ 1,038.96	$ 987.01	$ 831.17	$ 1,298.70	$ 654.55	$ 392.73	$ 0.47	$ 1.87
4	$ 1,142.86	$ 1,038.96	$ 935.06	$ 675.32	$ 1,298.70	$ 706.49	$ 518.18	$ 0.52	$ 1.82
Average	**$ 1,168.83**	**$ 987.01**	**$ 896.10**	**$ 766.23**	**$ 1,350.65**	**$ 681.82**	**$ 478.05**	**$ 0.51**	**$ 1.83**
SD	$ 108.14	$ 59.98	$ 88.72	$ 107.09	$ 59.98	$ 23.76	$ 57.89	$ 0.08	$ 0.03

PU: Production Unit; **SD**: Standard Deviation; **USD**: United States dollar.
Prices found in the last quarter of 2019.

live weight for animals weighing 200-300kg and $1.97/kg for those in the 300-500kg range. Buffaloes, in contrast, had a fixed price of $1.83/kg for steers and male calves weighing 200-500kg.

In summary, price differences favor buffalo milk but not buffalo meat, so it is logical that PUs orient their operations towards milk production. This indicates the importance of establishing commercialization channels for differentiated products so they reach consumers directly with labels that describe their nutritional characteristics. This would foment the consumption of buffalo products and their gradual incorporation into healthier diets [34]. Forging cohesive, competitive agribusiness chains would stabilize the commercialization of buffalo products and increase profitability. A first step would be for producers and industrialists to work with the authorities to elaborate norms for this species that would help establish fair prices for all participants and to formulate effective recall procedures to ensure that consumers receive products that are safe and clearly differentiated [12].

Zootechnical Indicators

Turning to productive variables, the DPBPS registered an average calving interval (CI) of 371.25 ± 7.50 days, similar to the figure reported by Cassiano *et al*. [35], of 380 ± 31 days (Table **6**) for Carabao, Jaffarabadi, Mediterranean, and Murrah buffaloes, though Barreto-Hernández *et al*. [36] reported a CI of 441.10 ± 163.23 days for F_1 swamp buffaloes crossed with river buffaloes. Bedoya *et al*. [37] evaluated the performance of female mestiza buffaloes, determining a CI of 13.83 ± 1.04 months, or 444 ± 31.2 days. These latter studies found longer intervals than our work. This difference may be due to the specific breed studied, the number of births, duration of lactation, level of management, and various types of stress that can produce prolonged periods of anestrus [35, 38].

Another explanation of the advantages found in our work could involve the type and number of samples selected for analysis. While several authors sustain that female buffaloes are physiologically capable of producing one calf per year [35, 39, 40], others propose that this species' natural calving interval (with no application of biotechnological reproductive measures) should show values just below 400 days to be deemed efficient [40]. The PUs that utilized assisted reproduction techniques had CIs within the optimum range.

For the calving rate, we determined an average of 89% ± 1%, which is within the range reported by Vázquez *et al*. (80-90%) [41], but higher than the 84% observed in the water buffalo study by Motta-Girando *et al*. [42]. Interestingly, all these values clearly exceed the 54.49% reported in Valenzuela-Hernández *et al.*'s [43] work on dual-purpose *cattle* production systems. These data indicate that, pragmatically, *cattle* raised in dual-purpose systems give birth once every two years, but female buffaloes can produce a calf practically once a year. Understanding the physiology, behavior, and birth signs in buffalo dams during eutocic and dystocic births will facilitate effective interventions to ensure the welfare of newborns, the health of dams, and future reproductive and productive performance [44]. This means a higher number of replacement animals and/or animals available for sale. In synthesis, the female buffalo's reproductive efficiency favors system autonomy by limiting the entrance of individuals but promoting the exit of animals for sale. We consider this a benefit of DPBPS from both the health and economic perspectives.

Table 6: Zootechnical Indicators of the DPBPS

Zootechnical indicator	PU				Average	SD
	1	2	3	4		
Calving interval (CI)	380	365	365	375	371.25	7.50
Parturition rate (%)	88%	90%	88%	90%	89%	1%
Age at first service (months)	20	19	20	20	19.75	0.50
Weight at first service (kg)	350	330	320	315	328.75	15.48
Weaning (days)	240	240	240	240	240.00	0.00
Weaning weight, males (kg)	230	260	160	220	217.50	41.93
Weaning weight, females (kg)	220	240	140	200	200.00	43.20
Weight of males at 1 year (kg)	260	280	210	285	258.75	34.25
Weight of females per year (kg)	250	270	200	270	247.50	33.04
Milk production per lactation (liter)	1360	1200	1440	960	1240.00	211.66
Milk for sale (liter)	5.67	5.00	6	4	5.17	0.88
Milk destined for calves (liter)	3	2	1.5	2	2.13	0.63
Mortality in adult animals (%)	1.0%	0.0%	1.5%	0.0%	0.6%	0.8%
Mortality in young animals (%)	2.0%	2.0%	2.0%	1.0%	1.8%	0.5%
Productive life of buffaloes (years)	20	18	15	15	17.00	2.45
Cull rate of buffalo cows (%)	15%	10%	12%	5%	11%	4%

PU: production unit; **SD**: standard deviation; **kg**: kilogram.

We determined a mean age at first service of 19.75 months ± 0.50 at a weight of 328.75 ± 15.48 kg. The latter value is similar (340 kg) to the report by Crudeli [45], though the females in that work required 22-24 months to reach it. Bedoya *et al*. [37] reported similar ages at first service: 27.27 ± 1.97 months. In synthesis, our DPBPS showed higher values than those in other studies. Thanks to their precocity, these females may be viable for reproduction sooner, though other important indicators –such as overall body condition– must be considered as well because of their strong correlation with the index of reproductive success and the optimal expression of the animals' biological potential [40, 45]. Giving calves access to a silvopastoral system at the time of weaning benefits the live weight change of calves and dams, while supplementing calves' diets during weaning provides additional advantages. Broader knowledge of specific weaning methods could enhance the welfare of the offspring and improve the reproductive efficiency of buffalo dams [46].

Mortality rates were 1.8% ± 0.5% and 0.6% ± 0.8% for young and adult animals, respectively. These figures are lower than those in Vázquez-Luna *et al*. [41], so we must clarify that the mortalities reported were attributed to accidents like births that occurred in deep water, snake bites, and parasitosis. These factors must be weighed when implementing preventive health programs. A key finding in this regard is that these PUs have not registered deaths due to predation, though this is a recurrent problem in conventional bovine (*Bos*) agroecosystems. River buffaloes are gregarious animals with group defense systems that effectively scare off many threats, as Hoogesteijn and Hoogesteijn [47] mentioned when reporting that buffalo production systems have a 25-fold lower probability of predation by large felines than the cattle-only system. This favors the production system and the entire ecosystem by reducing the need to hunt predators that may be species in danger of extinction to prevent future losses.

Regarding problems of hooves and mastitis, none of these DPBPS reported affectations. Important anatomical and physiological features of the river buffalo include narrower teat canals, stronger sphincters, greater production of bactericidal substances, stronger, wider, more flexible hooves, and a more robust immunological system. These help explain the species' low –even null– mortality rates and incidences of problems in their hooves and udders [25]. It also means that they require fewer veterinary services and/or medications, which reduces costs for services and inputs. It may be important to consider this rubric as it relates to the substantial economic losses caused by diseases that frequently affect cattle [8, 48].

The figure we recorded for milk production per lactation was1240 ± 211.66 liters (Table **6**), below the report in Brazil by Silva *et al*. [49], who calculated a broad range of 1500-4500 liters. In the production systems studied, milk was measured in units of volume, but using units of weight –pounds or kilograms– could highlight certain values, such as total solids, that can impact the selling price of buffalo milk due to its higher solids content. This means that it weighs more per liter than dairy cow milk. It is important to standardize the units of measure to ensure fairer prices for buffalo milk producers. It is also necessary to measure milk production in kilograms, a common practice in semi-intensive systems in Brazil, where cultivated grasses in the Eastern Amazonia include *Brachiaria* and *Panicum*. There, female Murrah and Mediterranean buffaloes and crossbreeds produced 1,806 kg of milk during lactations that lasted 262 days [39]. In Italy, female Mediterranean buffaloes in intensive production systems registered a production of 2,462 kg in lactations of 270 days [50]. Overall, the more intensive the production system, the higher the productivity, though it is necessary to analyze cost-benefit ratios from two key perspectives: economic and environmental, including indicators of animal welfare.

Mean daily milk production for sale in our study was 5.17 ± 0.88 liters, below (5.5-6.5 liters) the amount reported by Vázquez-Luna *et al*. [41]. PU3 had higher daily milk production, perhaps reflecting (i) the females' diet complemented with balanced feed; (ii) two milkings a day; and (iii) the percentage of milk consumed by calves (Table **6**). The average length of lactation was estimated at 240 days, similar to the value in Vázquez-Luna *et al*. [41] of 240-270 days, but below those reported by Marques *et al*. [39] and the *Associazione Italiana Allevatori* (AIA) [50]. In contrast, conventional bovine (genus *Bos*) production systems in Mexico's tropical wetlands register 148.83-255 days of lactation, with figures for daily milk production that range from 2-9 liters [22, 43, 51]. The river buffalo may not compete in terms of volume, but it certainly does in compositional values like fat, protein, and other nutrients that are important for the dairy industry and derivative products.

Regarding the criterion of the volume of milk consumed by calves, the average was 2.13 ± 0.63 liters. PU1 had the highest rate (3 liters) of the four PUs. This could explain why the weaning weight of calves there was greater than that at PU3 and PU4, though lower than at PU2. The average weaning weight for males was 210 ± 43.97, while for females, it was 195 ± 44.35. Calves were weaned at 240 days in all four PUs (Table **6**). Our figure for the days to weaning coincides with Vázquez-Luna *et al*. [41], but those authors mention higher values for the weaning weight of calves, possibly because they evaluated both dual-purpose production systems and systems exclusively for fattening animals. In the latter, all the milk that buffalo dams produced was consumed by calves, while in dual-purpose systems, a certain percentage is produced for sale.

On the issue of productive life, Vázquez-Luna *et al*. [41] reported a range of 20-25 years for female buffaloes, a value higher than ours (17 ± 2.45 years). Considering the calving interval and the estimated birth rates estimated in this evaluation, such as a long productive life could allow an index above 15 births per female (Table **4**). That result also reveals an outstanding performance compared to Holstein dairy cattle that, when raised in intensive systems, average only 2.7 births during their productive life [52]. The productive life of the buffalo dam's uterus is 15 years in all types of the production unit, so buffaloes are substantially longer-lived than conventional bovines. This is one advantage that buffaloes offer to increase production efficiency and lower costs [14]. As we mentioned in the description of social aspects, the producers studied have not completed a complete cycle of female buffaloes, so the value obtained is based on their perceptions but does coincide with reports in the specialized literature [40, 53].

Facility Condition Index, Machinery, and Equipment

The facility condition index generated medium-to-high values, but all four PUs scored above 50%. PU1 and PU2 coincided with scores of 57%, followed by PU4 at 71%. PU3 had the highest score at 83% (Table **7**).

The average facility condition index for the PUs was 68% ± 14% (Table **7**). A study of dual-purpose conventional bovines by Cuevas-Reyes *et al.* [56] in northwest Mexico presented significantly lower data for this index, as the stratum with the greatest technological advance tecnológico scored only 15% ± 20%, perhaps attributable to a low-level of capitalization in those PU. All four of the PUs in the present study have warehouses, corrals, milking

Table 7: Facility Condition and Machinery and Equipment Indices at the four DPBPS

PU	Facility condition index	Machinery and equipment index
1	57%	43%
2	57%	26%
3	86%	78%
4	71%	78%
Average	68%	57%
SD	14%	26%

parlors, and handling chutes, but significantly, only PU3 has an area specifically set aside as an eating station because this producer complements his animals' diet with balanced feed. At the other PUs, corrals have been used to complement pasture-based diets with minerals. All four PUs have cement floors, tubular structures, and laminated roofs in some areas –like the milking parlor– and sites for health and reproductive management. The females that are being milked enter those areas routinely during much of the year but spend most of the day in the pasture. Males, in contrast, spend the vast majority of their productive life outside, only entering the installations for de-worming, vaccinations, or preparation for sale (Figure **2**).

It is important to emphasize that it is rare to find eating areas in pasture-based production systems that provide little or no alimentary supplementation as this lowers investment for feed. A key aspect is that designing facilities for operations that produce female buffaloes must consider certain characteristics of this species, such as wider bodies and thermoregulation mechanisms. The aim is to provide conditions that enhance animal welfare [48, 54, 55].

Regarding the machinery and equipment index, the lowest value was for PU2 at 26%. The score for PU1 was 43%. PU3 and PU4 tied for the highest score at 78%. The mean environmental machinery and equipment index was 57% ± 26%. PU2 is the only one that does not have a tractor with implements like a harrow, plow, trailer, or cooling tank. All four PUs have scales, cryogenic thermos, cooling tanks (except PU2), mechanical milking equipment, water pumps, electric fences, and motorized vehicles like pick-up trucks. PU1 and PU3 also have cargo trucks (Figure **3**). Therefore,

Figure 2. Example of the facilities at one DPBPS.

A: holding area; **B**: milking parlor; **C**: handling chute.

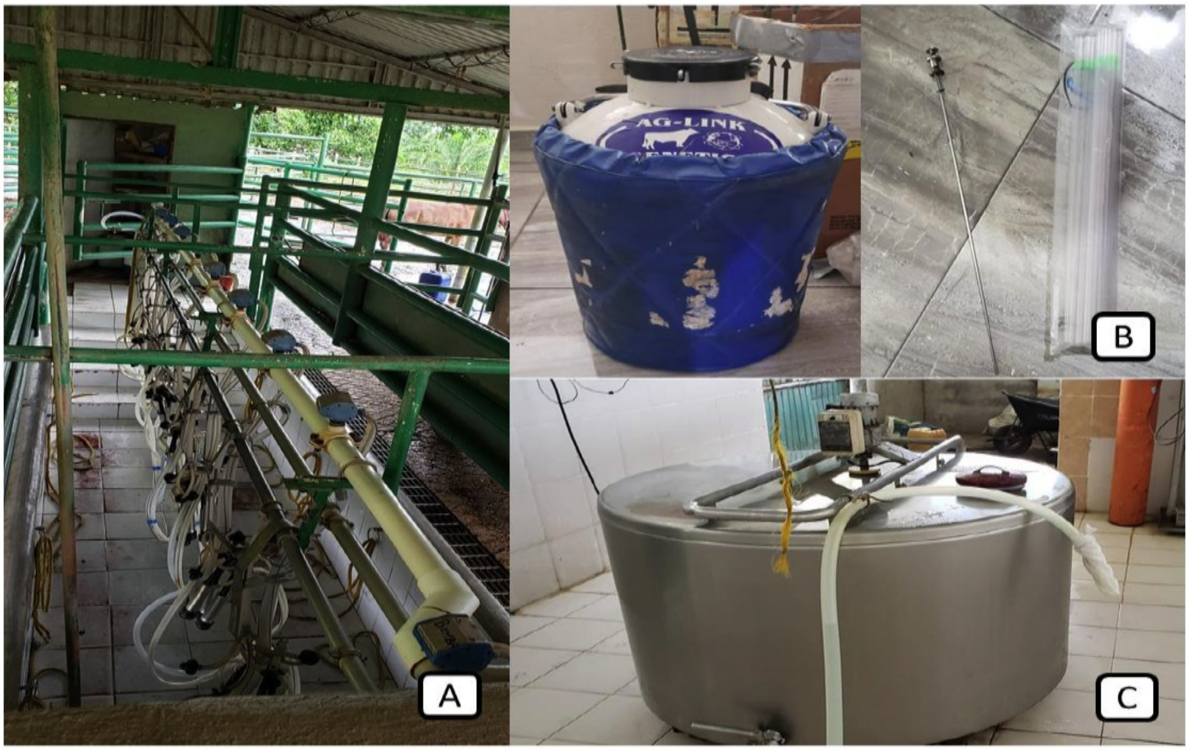

Figure 3: Illustrations of the equipment at the DPBPS.

A: milking equipment; **B**: artificial insemination equipment; **C**: milk cooling tank.

all four PUs had higher indices than those in the study by Cuevas-Reyes *et al*. [56], who estimated máximum values of 25% ± 27%that indicate moderate levels of capitalization.

These PUs have ample equipment and machinery that accords with their dimensions and reflects their owners' many years of experience in agricultural endeavors. However, most of that experience has involved conventional cattle, which have specific requirements due to their limited capacity to digest fibrous forage that requires selecting certain species of vegetation. The river buffalo, in contrast, does not require exotic, high-yield forage but readily consumes vegetation endemic to tropical wetlands, including plants considered weeds. They can also thrive in zones prone to flooding, which reduces the need for equipment and machinery.

We can suggest that the need for specialized equipment and machinery to maintain pasturelands, fertilization and weed control, and prepare land for planting introduced grass species can all be reduced substantially by breeding buffaloes under adequate management conditions in wetland regions. The only requirements are areas for conducting basic zootechnical handling that facilitate routine activities.

CONCLUSION

In the systems analyzed, the demand for labor was restricted and focused on animal care, milking, and maintenance of pastures. The direct supervisión of owners stood out at all four operations. Our comparison of river buffalo meat prices and fattening animals to cattle products show an advantage for buffalo milk but an unfavorable differential for animals destined for meat production. Significantly, no official tabulators establish prices for river buffaloes and their products. This absence is critical because it impedes generating clearly differentiated commercialization and distribution channels for buffalo products.

Concerning the sanitary dimensión, the priority must be to elaborate specific protocols for buffaloes and cease the use of routines designed for bovine cattle. These four production systems scored only medium marks for the facilities, machinery, and equipment utilized to tend to their animals and even lower ranges for their care of pasture áreas.

The productive and reproductive indicators evaluated herein reveal operations with healthy animals that can endure productively for long periods thanks to the precocity of female buffaloes and their ability to reproduce with an appreciable periodicity.

These factors produce a high number of replacement animals per buffalo dam with low cull rates due to biological causes that generate positive results for most of the economic and zootechnical indicators assessed.

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