

The behaviour and productivity of water buffalo in different breeding systems: a review

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ABSTRACT: This review examines the behaviour and productivity of the water buffalo (*Bubalus bubalis*) under different breeding systems and in relation to meat and milk production. At present, the steady increment in the consumption of products and sub-products of this species has generated the need to increase the number of animals incorporated into production by progressively expanding the use of stabling systems, reducing the space available to these animals, and applying techniques developed previously for meat and milk production in bovines. However, because such adaptations often fail to take into account important biological and behavioural features of these animals, they may result in serious problems of animal welfare. On the other hand, it is known that water buffaloes adapt well to humid tropical climates, especially in systems that provide extensive, continuous pastureland. These species are highly susceptible to thermal stress, a fact that leads them to constantly perform wallowing behaviour. For all these reasons, open-air and, above all, silvopastoral, systems represent attractive options because they combine the presence of forage plants with trees that provide natural shade and serve as wind barriers, thus attenuating the negative effects of tropical climates. These measures help increase productivity by promoting greater forage consumption and fostering the expression of the species' natural behaviours, but the reduction in human contact affects their welfare. Hence, this review concludes that welfare is a fundamental concept that must be taken into account in the development of systems for water buffalo production.

Keywords: outdoor systems; productivity; production systems; animal welfare; stress

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1. Introduction

Bubalus bubalis is the scientific name of the domesticated water buffalo (Abd El-Salam and El-Shibiny 2011). In Asia, the domestic water buffalo is generally classified into two principal sub-species (Yue et al. 2013); the river type and the swamp type (Perera 2008). These sub-species have distinct

chromosome karyotypes (50 and 48 chromosomes, respectively) (Yilmaz et al. 2012), and some differences in morphology (body frame, body weight, horn shape, skin colour) and behaviour (i.e., wallowing in water vs. mud). The best-known breeds are Murrah, Mediterranea, Jaffarabadi, Nili-Ravi, Surti, Mehsana, Kundi, Nagpuri and Bhadawari (Bartocci et al. 2002; Cruz 2007; Das et al. 2008;

Thiruvankadan et al. 2013). The water buffalo is a valuable species in part because it is considered a multipurpose animal (Abd El-Salam and El-Shibiny 2011; de la Cruz-Cruz 2014) since its meat, horns and skin can all be exploited, as can its rich and nutritious milk, which may be converted into many kinds of cheese, primarily mozzarella. In addition, buffaloes are valuable beasts of burden and work animals (Spanghero et al. 2004; Cavallina et al. 2008; Das and Khan 2010; Michelizzi et al. 2010; Aspilcueta-Borquis et al. 2012; da Luz et al. 2013). For these reasons, the domesticated water buffalo is often called “the living tractor of the East” since it is relied upon for ploughing (Bakkannavar et al. 2010) and transportation in many parts of Asia (Chantalakhana and Bunyavejchewin 1994).

Breeding water buffaloes does not require high capital expenditures because they are undemanding in terms of food and shelter (Czerniawska-Piatkowska et al. 2010), and are well-adapted to the wet conditions often encountered in flooded native pastures where bovine cattle do not normally thrive (Camarao et al. 2004). This is possible because the water buffalo has long benefitted from its efficient utilisation of a low-quality, high-roughage diet (Czerniawska-Piatkowska et al. 2010). However, it is clear that greater success can be achieved by optimising the conditions for milk and meat production (Bernardes 2007). Some studies have shown that higher productivity can be achieved through the use of systems that reduce the surface areas and require less capital investment in herds than methods which demand larger investments in production inputs (Dikdan and Garcia 2012), but this can have undesirable consequences for animal welfare, since space restrictions may adversely affect various aspects including health and social behaviour (De Rosa et al. 2009a; de la Cruz-Cruz 2014). Therefore, the aim of this review is to evaluate the effects of different breeding systems on the behaviour and production of the water buffalo.

2. Characteristics of the water buffalo

The principal advantageous characteristic of the water buffalo is its special ability to subsist on coarse feed, straw and crop residues and to convert these materials into protein-rich lean meat that is low in cholesterol (Desta 2012). This efficiency in transforming pasture may be due to this species' slow, efficacious chewing motion that involves

more developed muscle fibres for rumination than in the case of cattle, including the *digastric muscle*, the *masseter muscle*, the *pterygoid muscle*, and even the tongue ($P \leq 0.05$) (Vega et al. 2010). Other important features include its larger corporal volume, slower movement, smaller outflow rate, and higher bacterial activity (Napolitano et al. 2013).

The water buffalo is well-adapted to humid tropical climates, but prolonged exposure to high temperatures can trigger a series of dramatic changes in its biological functions that directly affect thermoregulation. These alterations include depressed food intake, efficiency and utilisation, disturbances in water metabolism, protein, energy and mineral balances, hormonal secretions, enzymatic reactions, and blood metabolite levels (Castro et al. 2008; Marai and Haeeb 2010). The water buffalo has dark skin sparsely covered with hair (Khongdee et al. 2013). As a species, it is highly susceptible to thermal stress, especially under direct exposure to the sun's rays, since its evaporative cutaneous cooling mechanism is weak owing to the low density of sweat glands (Das and Khan 2010). For these reasons, the water buffalo has poor thermoregulation and often requires shade, or water in which to wallow (Desta 2012), a behaviour that confers the additional advantage of providing protection against external parasites (De Rosa et al. 2005). In hot conditions, the water buffalo increases its blood volume and flow to the skin surface in order to maintain a high skin temperature and facilitate heat dissipation while it lolls in mud or water (De Rosa et al. 2009b). In situations of stress, activation of the autonomic sympathetic system induces the release of epinephrine, which has effects similar to those of cortisol as it increases body temperature and the rate and depth of respiration (Koknaroglu and Akunal 2013; de la Cruz-Cruz 2014).

3. Trophic behaviour

The water buffalo has conserved the semi-wild type of behaviour that is its nature (Das et al. 2007). The feeding behaviour of the water buffalo is similar to that of cattle raised in similar conditions, but these two species are differentiated by the wallowing behaviour that characterises the former (Barrio et al. 2000). Both water buffaloes and cattle spend 99% of their waking hours ingesting food, ruminating, resting and drinking water; the remaining 1% is devoted to locomotion and other activities

(Fundora et al. 2007). During the day, these animals generally pass the time by consuming pasture and ruminating, but they probably also graze at night (Fundora et al. 2001). In this regard, Barrio et al. (2000) reported that food ingestion increases as daylight hours advance, although these observations run counter to the findings reported in Thomas et al. (2005), who observed that water buffaloes spend significantly more time eating during the day compared to the night. On this point, Odyuo et al. (1995) affirm that eating, idling and walking were more frequent during daylight hours, while ruminating and sleeping were the predominant activities performed at night. Studies that evaluated 16-month-old water buffaloes of the Bufalipso breed that were allowed access to feed (*Panicum maximum*) and water *ad libitum* showed that, compared to bovine cattle, those animals devoted more time to rumination (53.7 vs. 37.9%), less time to ingesting forage (22.4 vs. 32.9%), and more time at rest (31.3 vs. 27%) (Fundora et al. 2007). Antkowiak et al. (2012) have also reported that these beasts spend most of their time grazing (58.6%), followed by ruminating (28.2%), lying down (26.5%), wallowing (12.9%), and standing (1.4%). They found that when these animals had access to a pond or ditch, the proportion of wallowing was two times greater than when they had access to a stream ($P < 0.05$). Napolitano et al. (2007), meanwhile, reported that during summer and autumn the animals displayed higher levels of inactivity, as shown by increased lying down and ruminating behaviours. Other studies have found that activities like locomotion and exploration ($P \leq 0.01$), social interaction (sniffing, nuzzling), and allogrooming ($P < 0.01$ and $P < 0.05$, respectively) all increase when the water buffalo has access to a concrete pool (De Rosa et al. 2007). In this regard, expression of Orexin A and its receptor OX (1) has been found in the brains of water buffaloes. This protein modulates feeding behaviour, the sleep-wake cycle, and energy homeostasis, as well as associated drinking behaviours (Tafari et al. 2009).

In contrast, observations of crossbred water buffaloes raised under feedlot conditions reveal that the duration of standing behaviour was significantly shorter (659 vs. 857 min; $P \leq 0.001$), while the lying posture was longer (643 vs. 578; $P \leq 0.10$) than in tropical grade Brahms (Vega et al. 2010). The same authors utilised two video camcorders installed in corrals with Brahms and crossbred water buffaloes in an attempt to determine their

respective frequencies of food intake, performance, and nutrient digestibility. Their results show that the larger dry matter intake of water buffaloes resulted in higher total crude (680 vs. 502 g; $P \leq 0.05$), total digestible nutrient intake (3.92 vs. 2.67 kg; $P \leq 0.05$), and metabolised energy intake (14.2 vs. 9.7 kcal; $P \leq 0.05$), due to higher grass consumption (6.52 vs. 4.48 kg/day; $P \leq 0.05$). Those water buffaloes also had higher percentages of body weight/day (2.17 vs. 2.03), and devoted more time to food consumption (449 vs. 445 min/day) and drinking (122 vs. 46; $P \leq 0.05$). In similar studies carried out by Fundora et al. (2007), observations included lower values for water buffaloes compared to bovines in terms of forage ingestion (25.2 vs. 31.9 kg/day) and total dry material (6.6 vs. 8.0 kg/day), and a lower rate of forage consumption (2 vs. 3.1 kg/h) with fewer ruminating movements (6.4 vs. 7.1 min).

4. Meat productivity

Water buffalo meat is gaining popularity and its production is growing rapidly in producing countries (Tajik et al. 2010; de la Cruz-Cruz 2014). The price of buffalo meat is much lower than beef, chevon, mutton, pork or poultry and is, therefore, the cheapest source of protein available to the poorer sectors of society (Ranjhan 2013). Some studies comparing water buffalo meat to beef have shown that the nutritional and organoleptic properties of the former are, overall, similar and in some respects – colour, rheology, flavour, etc. – even superior to those of the latter (Di Luccia et al. 2003; Kandeepan et al. 2009) although they recommend sacrificing animals at a relatively young age in order to improve the marketing properties of the meat and assure better physicochemical and organoleptic characteristics (Andrighetto et al. 2008). However, meat is often introduced into commercial circuits without being identified as such (Atencio-Valladares et al. 2007), so most buffalo meat may actually be sold as “beef” (Andrighetto et al. 2008) because the taste is virtually indistinguishable (Ban-Tokuda et al. 2007).

The productive parameters for the three principal breeds of water buffalo were reported by Jorge et al. (2005), who describe in-canal yields for the Murrah, Jaffarabadi and Mediterranean breeds of 53.9, 54.39 and 54.32%, respectively. However, they found no differences in terms of the anterior areas or hindquarters, or the in-canal yields of the different cuts that have the highest commercial value

($P > 0.05$). With respect to the live weight of four-year-old water buffaloes, males were found to be heavier than females (515.34 vs. 496.44 kg) and to have greater in-canal weight (236.08 vs. 234.60 kg), though these differences were not statistically significant ($P > 0.05$). However, the weight of the loin area was greater in males, as was that of the hooves and skin ($P \leq 0.05$) (Akdag and Celik 2006). For mixed-breed Murrah and Mediterranean water buffaloes raised primarily on forage plants like *Brachiaria humidicola*, *Brachiaria decumbens* and *Paspalum plicatulum*, differences were found between non-castrated and castrated males in terms of fresh in-canal weight (222.75 vs. 210.45 kg), the thickness of dorsal fat (0.67 vs. 0.77 cm), yields for boneless cuts (55.60 vs. 54.89%), and the percentage of bone (12.41 vs. 12.11%), respectively (Atencio-Valladares et al. 2007). A study of 15-month-old, castrated Murrah water buffaloes determined that confinement periods of 75 and 150 days did not affect such sensorial characteristics as flavour, aroma and colour (Andrighetto et al. 2008). A comparison of water buffaloes and bovine cattle found no significant differences in body weight; however, carcass efficiency and the cost of better quality meat production per kg were higher and lower, respectively, for water buffalo calves (Chashnidel et al. 2007). Despite such findings, water buffaloes destined for meat production are comparable to beef cattle in terms of growth rate, feed conversion efficiency, and carcass characteristics (Neath et al. 2007). The buffaloes grow at a slower daily rate than bovines (930 vs. 1040 g/day; $P = 0.07$), but achieve a comparable live weight (312 vs. 329 kg), while carcass measurements confirmed the diversity in body shape among species, with water buffaloes having shorter carcasses than the bovines (108.7 vs. 114.2 cm) (Spanghero et al. 2004).

5. Milk productivity

The water buffalo is the second most important species in the world in terms of milk production, after dairy cows (Coroian et al. 2013), and produces the highest quality milk of any domestic animal (Senosy and Hussein 2013). As mentioned earlier, water buffalo milk is used primarily to produce cheeses, especially mozzarella (Aspilcueta-Borquis et al. 2012). Cheeses made from buffalo milk display typical body and textural characteristics, but are unique in nature and have superior sensory qualities (Hofi 2013).

It has been reported that milk production during lactation periods of 270 days is 2 220 kg with 8.4% fat and 4.6% protein (Borghese 2013). In contrast, Bartocci et al. (2002) report an average production of 8.64 kg/head/day, composed of 47.71 g/kg of protein and 87.08 g/kg of fat. For water buffaloes in Italy, meanwhile, the average production reported for a 270-day lactation period were 2286.8 kg of milk with 196 kg of fat, representing 8.59%, and 104.7 kg of protein, representing 4.55% (Rosati and Van Vleck 2002). Differences in milk production among the different genetic groups of water buffaloes have also been found: 1651.4, 1592.2, 1578.3, and 1135.5 kg for Murrah, Mediterranean, Mestizo and Jafarabadi females, respectively (Ramos et al. 2007). Studies have been conducted to determine the relation between different phenotypic characteristics and milk production. Findings indicate that black-coloured water buffalo cows produce larger quantities of milk than females of dark brown colour (2195 ± 34 vs. 1863 ± 30 kg). No differences in milk production were observed in cows with different-shaped horns or horns of distinct size. With respect to temperament, observations show that docile animals produce more milk (2120 ± 27 kg) than nervous (1829 ± 49 kg), or aggressive ones (1743 ± 147 kg) (Bharadwaj et al. 2007).

Khan and Akhtar (1999), meanwhile, reported that the average milk production of Nili-Ravi buffaloes was 2020.04 ± 44.59 litres during a lactation period of 277.42 ± 5.7 days, while a study of the Mediterranean breed found a milk production of 4.52 kg/day with 4.13% protein, 6.59% fat, 17.01% total dry material, 10.47% non-fat dry material, and 18.98 D acidity (Macedo et al. 2001). Salari et al. (2013) reported that primiparous Mediterranean buffalo cows produced 8.47 kg of milk per head ($P \leq 0.01$), 12% below that of multiparous females. They also found that milk production increased between days 16 and 60 (11.35 kg/per head), that fatty content was higher ($P \leq 0.01$) at the end of the peak production period (8.64%), and that protein levels increased at the onset and end of lactation (4.84 vs. 4.93). Finally, Yilmaz et al. (2012) reported milk yields of 24–26 l/day during a lactation period of 225 ± 6 days. Total milk solids were $17.7 \pm 0.3\%$, protein was $4.2 \pm 0.1\%$, and fat was $8.1 \pm 0.2\%$. Taking into account all these elements, milk yields are 40% greater than those for bovine milk (Andrade et al. 2009). Thus, the price of buffalo milk is about three times that of dairy cattle milk (Rosati and Van Vleck 2002).

6. Production systems

6.1. Silvopastoral systems

Livestock-raising (of ruminants) contributes to the production of foods with high biological value (Castro et al. 2008). In an effort to improve the productive yields of water buffaloes, silvopastoral systems combine trees and forage, which provide a wind barrier and reduce the negative effects of tropical climates by attenuating thermal stress. These systems are utilised for the livestock of several different species in management regimes (Cubbage et al. 2012). The animals' natural pastures provide an environment in which animals are free to perform their characteristic behaviours (Braghieri et al. 2011b). Appropriate environmental stimulation also fosters good welfare, and in adequately enriched conditions positive indicators of welfare – such as play behaviour – tend to be more common (Napolitano et al. 2009). Adopting silvopastoral systems for buffalo production in tropical areas can also prevent energy loss due to thermolysis (Garcia et al. 2011).

Providing shelter and shade decreases thermal stress as reflected in reports of lower rectal temperatures (39.14 ± 0.07 vs. 40.00 ± 0.10 °C), lower plasma cortisol (2.14 ± 0.24 vs. 3.38 ± 0.37 ng/ml), and a significant reduction in water consumption (29.71 ± 0.86 vs. 34.14 ± 1.06 l/head/day), accompanied by increases in forage consumption (5.88 ± 0.18 vs. 6.44 ± 0.19 kg/head/day) (Khongdee et al. 2013). The effects of these systems with shade are also shown in greater weight gain – 757 vs. 337 g/animal/day compared to animals raised under direct sunlight – lower rectal temperatures (38.3 °C vs. 39.1 °C), and lower respiratory frequency (22.6 vs. 48.4 mov/min) (Castro et al. 2008). Another study evaluated adult water buffalo cows in silvopastoral systems with and without shade, and reached the conclusion that the animals that were provided with an area of 19% shade significantly reduced their heart rates and rectal temperatures, but maintained other physiological parameters close to normal values (Garcia et al. 2011).

Recently, Peixoto et al. (2012) evaluated buffaloes raised in a silvopastoral system supplemented with agro-industrial sub-products (eg. corn, coconut and palm oil) and observed a weight gain of as much as 1 kg/day (± 0.3), with in-canal yields of 57–59%. They also observed that when the animals' diet was supplemented with palm oil higher amounts of fat

were produced (17.1 ± 1.5), together with improved marbling scores (9.3 ± 0.6). The *longissimus dorsi* muscle showed no differences in terms of the cutting force required, and results for colour revealed an intense red hue probably attributable to high pH values (6.11 ± 0.1).

Researchers also evaluated 15- to 30-month old Murrah buffalo cows to measure the effect of a ventilator and water aspersion apparatus applied during 10 min at intervals of 2 h, followed by the ventilator alone, and compared to a control group. This team found that the animals in the first group spent more time ruminating (35.24% vs. 31.04% vs. 30.23%, respectively). With respect to food consumption, the ventilator-only group devoted the most time to this activity (28.75%), followed by the ventilator-plus-aspersion group (26.35%) and, finally, the control group (22.04%) during a 24-h period (Vijayakumar et al. 2009). It is also well known that the water buffalo achieves higher levels of welfare during hot periods of the year as long as they are provided with access to ample facilities for wallowing (Antkowiak et al. 2012). A study by De Rosa et al. (2009a) indicates that in the presence of a pool, together with a larger space allowance, wallowing represents the preferred posture, possibly because it is the most important means of dissipating heat, and may promote non-agonistic social interactions ($P < 0.01$), since a higher number of social interactions (sniffing and nuzzling) were observed, and social licking was also noted when the animals had broader living spaces ($36 \text{ m}^2/\text{head}$ vs. $10 \text{ m}^2/\text{head}$; $P < 0.01$ and $P < 0.05$, respectively).

6.2 Outdoor systems

In their comparison of housing systems for cattle, Braghieri et al. (2011a) noted that animals kept in a free-range system spent more time walking ($P \leq 0.05$), feeding ($P \leq 0.01$) and standing ($P \leq 0.01$), and showed reduced agonistic behaviour ($P \leq 0.05$). As a result, average daily weight gain ($P \leq 0.05$), slaughter weight ($P \leq 0.05$) and body condition scores ($P \leq 0.01$) for these beasts were all higher than those of bulls that were raised in confined conditions. In this regard, water buffaloes raised in rotational grazing systems with pastures made up of 21.5% star grass (*Cynodon nlemfuensis*), 21% nadi bluegrass (*Dichantium caricosum*) and sheda grass (*Dichantium annulatum*), 18% bahia grass (*Paspalum notatum*), 5.9% native legumes,

22.7% razor grass (*Paspalum virgatum*), and 10.9% lizar grass (*Sporobolus indicus*), showed an average weight gain of 706 g/day at 23.1 months of age, with yields of 48.3%. Bones represented 20.3% of body weight, and fat 9% (Fundora et al. 2004).

Studies have also shown that when allowed access to an outdoor paddock, the animals used their time to walk, trot and explore the environment, and that this exercise had a positive effect on claw conformation (Loberg et al. 2004). Water buffaloes in India have been evaluated to determine the effect of livestock-raising systems, and one result was that milk production was found to be higher in open-air systems (8.12 ± 0.002 vs. 7.77 ± 0.002 kg). In addition, higher scores for cleanliness were found (2.80 ± 0.05 vs. 2.41 ± 0.05) compared to conventional stabling methods, while this latter system also produced a higher number of animals with lameness (0.01 ± 0.01 vs. 0.10 ± 0.02). It has also been observed that cows left free to graze devote more time to feeding than those first kept in stables before being released into the open (78 vs. 25%, respectively), and those cows tend to walk longer distances (Lopes et al. 2013). Systems that allot greater space to cows also lead to higher milk yields ($P < 0.05$) with no differences in protein or fat content (De Rosa et al. 2009a). On this point, Tripaldi et al. (2004) evaluated the beneficial effects on buffalo cows of an outdoor yard with a space allowance of 500 m² per head with respect to eating behaviour ($P \leq 0.001$), as well as grazing and bathing performance. The effect of space on 7- to 10-day-old calves was reported by Grasso et al. (1999), who found that among animals held in larger corrals (2.6 m indoor m² + 2 outdoor m² vs. 2.6 and 1.5 m² indoor), those that were allowed access to an exterior area spent less time at rest ($P \leq 0.01$) and slept with more legs extended ($P \leq 0.001$). Those calves were also found to have higher quantities of antibodies ($P \leq 0.05$). In contrast, Stafford and Gregory (2008) reported that the use of more intensive grazing systems generally reduces opportunities for shade and shelter and results in less time available to spend on self-maintenance activities such as grooming, in addition to a reduction in human-animal contact. Human-animal interactions are recognized to have an impact on productivity, behaviour and welfare (Cavallina et al. 2008). Extensively reared animals often show an excitable and anxious temperament, which makes appropriate handling difficult (Probst et al. 2012). During the productive stage, there may be problems

in terms of welfare, since feeding exclusively on grasses does not totally satisfy the animals' energy requirements. A food restriction of 50–75% (kg of dry material) has been related to an increase in vocalizations and aggressive reactions due to competition for food (Schutz et al. 2013). It is known that balanced nutrition can improve milk production in water buffalo cows (Sarwar et al. 2009), so proper feeding during lactation has a positive influence on the characteristics of the milk produced and on such behaviours as social interaction and total standing and ruminating times (Thomas et al. 2005).

6.3 Intensive systems

Confinement is a technology that can be applied in water buffalo-raising to increase productivity indexes by providing balanced feed as a means of improving weight gain (Andrighetto et al. 2008). Nowadays, buffaloes are often managed and fed in intensive systems (in feed-lots for fattening and slaughtered at 15 months of age, once they surpass 400 kg live weight) where the cows are kept loose in paddocks and milked mechanically twice a day (Borghese 2013). Although extensive systems are widely used in tropical climates, the corral approach for intensive fattening is an option that is often adopted for the final stage of the commercialisation process because it shortens the productive cycle (Titto et al. 2010). Of course, this requires systems based on balanced feed administered in confinement, but it does foster greater daily weight gain and reduces slaughtering age, both of which impact meat quality and meat supplies positively during the down season (Jorge et al. 2005).

Another common practice employed with stable animals is castration. On this topic, Menegucci et al. (2006) state that castrated animals give higher hindquarter yields, precisely the area with the cuts that provide the highest commercial value. However, Martins et al. (2011) conducted evaluations designed to determine the level of stress that water buffalo bulls destined for meat production experience during castration. They found weight loss in the first 24 h of treatment, and observed that the animals showed signs of moderate pain on palpation, indicated by flexed hind limbs and arched backs, followed by mild foot stamping. The serum cortisol concentrations in non-castrated males

(0.63 µg/dl) were both lower ($P \leq 0.05$) than those observed for surgically-castrated bulls (1.58 µg/dl).

Other experiments have compared the effectiveness of fattening systems between water buffaloes and Brahman cattle. The higher body weight gain observed in the former can be attributed to higher feed intake, more efficient ruminative chewing, and energy conservation behaviours (Vega et al. 2010). However, limitations of space, diet and social environment can threaten the welfare of animals raised in intensive exploitations (LeNeindre 1993), thus causing stress (Grasso et al. 1999). In a comparison of male buffaloes and bovine cattle kept in stables, lower weight gain (g/day) during fattening was found (1245 vs. 1135, respectively) (Spanghero et al. 2004). For cattle, Nelore Titto et al. (2010) evaluated two housing systems used for fattening – group pen vs. individual pen – but found no relation between reactivity and feedlot systems, although cortisol values were higher in the animals held in the group pens (28.36 ng/mg) than in those kept in individual pens (18.79 ng/mg). Also, fattening time affected cortisol levels ($P \leq 0.09$ individual; $P \leq 0.01$ group).

Of course, the increase in dairy buffalo production has led to greater use of intensive management techniques and the mechanisation of daily farm activities (Thomas et al. 2005). Recently, intensification methods and livestock-raising techniques originally developed for dairy cattle have been increasingly put into practice for water buffaloes (machine-milking, artificial breeding, loose yard and cubicle housing systems, etc.) in order to increase milk production. However, these measures expose the animals to sudden environmental changes that entail physical and physiological stress (De Rosa et al. 2009b). In this regard, Cavallina et al. (2008) used the focal sampling technique to conduct observations intended to determine the behavioural responses of animals to milking machines and the administration of oxytocin in primiparous and multiparous buffalo cows. They found a higher frequency of acute, stress-related behaviours during milking in the primiparous mothers that included kicking (36.67% vs. 24.36%), defecating (5% vs. 2.56%), pulling the teat cup off the teat (11.67% vs. 5.13%), and urinating (48.33% vs. 11.54%). Some correlations between animal behaviour during milking and oxytocin administration were found; in particular, kicking, stomping and urinating appeared to be significantly related to this exogenous requirement ($P < 0.001$). The prevalence

of buffalo cows injected with oxytocin during milking may also be an indicator of the quality of the human-animal relationship (De Rosa et al. 2005). Oxytocin is a very common nonapeptide neurohypophysial hormone that is implicated in milk expulsion (Cosenza et al. 2007). It is well known that the neurohormonal reflex of milk expulsion can be easily inhibited by disturbances during milking or when an animal experiences stress (Thomas et al. 2005). When the body confronts a stress factor, the hypothalamic-pituitary system is stimulated, causing the hypothalamus to release corticotrophin, a factor that, in turn, triggers release of the adrenocorticotrophic hormone (ACTH). Under the influence of ACTH, the release of cortisol from the adrenal gland increases and, as a result, glycogenolysis, blood pressure and mental activity all rise, and fatty acids are mobilised from adipose tissues (Koknaroglu and Akunal 2013).

In dairy cows, voluntary restriction of movement and limitations on the expression of natural behaviours has been observed (Popescu et al. 2013). Evaluations of space availability with buffalo cows have found that animals housed with 20 m²/head had higher milk production ($P \leq 0.05$) at the onset (74 to 104 days) and end of lactation (around 230 days) (Vecchio et al. 2009). Roca-Fernandez et al. (2013), meanwhile, evaluated dairy cows kept in stables and found higher milk production (27 vs. 20.1 kg/head/day; $P \leq 0.001$), although the cows allowed to graze in open pastureland devoted more time to food consumption (522 vs. 173 min; $P \leq 0.001$), and less time lying down (212 vs. 411 min; $P \leq 0.001$), standing (85 vs. 236 min; $P \leq 0.001$) and ruminating (141 vs. 244 min; $P \leq 0.001$). The higher rates of milk production under stabling conditions are due to the dietary supplementation the cows receive. A study designed to determine the most suitable level of protein and energy for milk production in multiparous water buffalo cows found that a diet with 6.63 MJ/kg of DM and 179.50 g/kg of raw protein led to a mean milk production of 13.08 kg/day with a composition that included 76.58 g/kg of fat, 46.14 g/kg of protein, and 39.94 g/kg of casein (Terramocchia et al. 2012). Bartocci et al. (2002) reported the dry matter intake requirement of for buffalo herds to be 10.61–16.75 kg/day. Milk production in water buffalo cows fed with corn and sorghum silage was determined to be 9.29 and 9.55 kg/day, respectively, although urea content differed significantly, varying from 39.1 mg/dl to 45.55 mg/dl,

Table 1. Advantages and disadvantages of the different production systems for water buffalo

Silvopastoral systems	Open-air systems	Intensive systems
Advantages		
Provide natural shade (Cubbage et al. 2012)	↑ Time for walking ($P \leq 0.05$) and eating ($P \leq 0.01$) (Braghieri et al. 2011b)	↓ Space required for production (Dikdan and Garcia 2012)
Allow the normal wallowing behaviour of this species (Antowiak et al. 2012)	↓ Agonistic behaviours ($P \leq 0.05$) (Braghieri et al. 2011b)	Production of foods of animal origin during periods of scarce pasture (Jorge et al. 2005)
↑ Non-agonistic social interactions such as sniffing and nuzzling ($P < 0.01$) (De Rosa et al. 2009a)	↑ Weight gain ($P \leq 0.05$) (Braghieri et al. 2011b)	Control of diet (Bartocci et al. 2002)
↓ Reduced rectal temperature (39.14 vs. 40 °C) (Khongdee et al. 2013)	↑ Weight at slaughter ($P \leq 0.05$) (Braghieri et al. 2011b)	↑ Greater use of the techniques of milk production used with bovine cattle (eg. 2 milkings per day) (Borghese 2013)
↓ Plasma cortisol concentration (2.14 vs. 3.38 ng/ml) (Khongdee et al. 2013)	↑ Body condition ($P \leq 0.01$) (Braghieri et al. 2011b)	↓ Lower age at slaughter (400 kg at 15 months of age, approximately) (Borghese 2013)
↑ Food consumption (5.88 vs. 6.44 kg/head/day) (Khongdee et al. 2013)	Weight gain of 706 g/day (Braghieri et al. 2011b)	↑ Increased production indexes improve weight gain (Andrighetto et al. 2008)
↑ Ruminant movements (22.6 vs. 48.4 mov/min) (Khongdee et al. 2013)	↑ Space for walking with positive effects on claw conformation (Loberg et al. 2004)	Weight gain in the fattening phase of up to 1135 g/day (Spanghero et al. 2004)
↑ Weight gain of 757 vs. 337 g/animal/day (27); up to 1 kg/day with supplements (Peixoto et al. 2012)	↑ Higher milk production (8.12 ± 0.002 vs. 7.77 ± 0.002 kg) (Lopes et al. 2013)	
	↑ Higher cleanliness scores (2.80 ± 0.05 vs. 2.41 ± 0.05) (Lopes et al. 2013)	
	↑ Antibody titres ($P \leq 0.05$) (Grasso et al. 1999)	
	↓ Time at rest ($P \leq 0.01$) (Grasso et al. 1999)	
Disadvantages		
The systems based on pastures do not provide the necessary nutritional requirements (Schutz et al. 2013)		↑ Stress caused by reduced space (De Rosa et al. 2009a)
Scarcity of food may provoke fighting due to competition (Schutz et al. 2013)		↑ Behaviours during mechanical milking such as kicking, defecating, urinating, and pulling the teat cup off the teat (Cavallina et al. 2008)
↓ Milk and meat production during dry seasons (Cavallina et al. 2008)		↑ Animals with laminitis (Cavallina et al. 2008)
↓ Time for self-maintenance and grooming activities (Stafford and Gregory 2008)		↑ Agonistic behaviours (Cavallina et al. 2008)
↓ Reduced human contact (Stafford and Gregory 2008)		↓ Time for walking (Stafford and Gregory 2008)
↑ Animals are more restless during handling (Probst et al. 2012)		No space available for wallowing behaviour (Tripaldi et al. 2004)
		↑ Increase in periods of inactivity (Tripaldi et al. 2004)

respectively (Barile et al. 2007). Better results have been achieved in water buffalo cows fed *ad libitum* a diet with a forage/concentrate ratio of 53/47 that contained alfalfa hay (10%), corn silage (43%) and

concentrate (47%). In the first evaluation period of 58 days, production was 13.08 kg/day, however, by day 114 this had decreased to 10.24 kg/day (Bartocci and Terramoccia 2010).

Additional findings have demonstrated that keeping and feeding dairy cows in yards results in an increase in lameness and mastitis and, perhaps, also in agonistic behaviour, but reduces time spent walking (Stafford and Gregory 2008). In dairy buffaloes with hoof or leg problems, a decrease in ruminant motility was found, while haematological indexes showed significant declines in Hb, PCV and TEC (Kalsi et al. 2002). Finally, water buffalo cows kept in intensive conditions with no access to ample yards and mud holes may extend their periods of idling with negative effects on welfare (Tripaldi et al. 2004), for it is well known that in confined management systems the biology and behaviour of the animals are often ignored and, therefore, can lead to severe problems in terms of welfare (Loberg et al. 2004). The overall advantages and disadvantages of breeding systems for the water buffalo are shown in Table 1.

7. Conclusions

The water buffalo is a species with excellent zoot-echanical characteristics for both milk and meat production. As a result of the steady increase in the consumption of these products, ranches face the need of increasing the number of animals raised for these purposes. In this regard, better productive results have been achieved primarily on dairy ranches because native grasses do not always satisfy the animals' energy requirements. Studies have also shown that better production results are achieved when the animals are given balanced food supplements to complement their grass-based diets. On the other hand, stable-based systems have been criticised because they reduce the holding area for individual animals, which can negatively affect welfare. Although this species may seem to be quite similar to bovine cattle, it performs one distinct, and particularly important behaviour that cattle do not: wallowing in mud or water as a means of thermoregulation and maintaining homeostasis. Thus, silvopastoral systems offer productive advantages and can improve the welfare of the water buffalo because this is a mainly an herbivorous species and the presence of trees in the terrain provides shade that functions to maintain their body temperature. In addition, these systems allow the animals to perform typical behaviours due to the availability of ponds or other small bodies of water; a disadvantage of this system is that the reduced human contact may affect their welfare.

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