

Comprehensive Assessment of Economic, Productive, Phenotypic, and Morphometric Traits in Azikheli Buffalo Breed of Northern Pakistan

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COMPREHENSIVE ASSESSMENT OF ECONOMIC, PRODUCTIVE, PHENOTYPIC, AND MORPHOMETRIC TRAITS IN AZIKHELI BUFFALO BREED OF NORTHERN PAKISTAN

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ABSTRACT

The study was conducted to illuminate the phenotypic, morphometric, and productive characteristics of the Azikheli buffalo breed. One thousand two hundred pure Azikheli buffaloes (male: female) were randomly selected from the main hub of the Azikheli buffalo breed in Swat (Azikhel). The data were analyzed for comparison and frequency distribution. Phenotypic characteristic of the female buffalo shows that more than 73 % of the body color was golden yellowish. In contrast, in males, this value was 83 %, followed by white-albino and grayish colors. The shape of horns were semi sickle and grayish in color. Morphometric parameters of the breed indicated that the average body weight of female and male buffaloes was 480 ± 20 kg and 422 ± 20 kg, body length 131.3 ± 2.5 cm vs. 121.4 ± 1.3 , height at withers 127.48 ± 0.5 cm vs. 124.9 ± 0.4 cm and heart girth 185.8 ± 3 cm vs. 172.5 ± 2 cm. The male is slightly narrow, and more compact in body structure than the female. Average daily milk production was 7.80 liters with a range of 5-16 liters/day. The milk fats % was very high compared to other local buffalo breeds and ranges from 6.5 to 9.70 g/100 g and make the milk selling at a high rate in the swat local market ranges from 250-270 Pakistani rupees/liter compared to other buffalo milk (200-220 Pakistani rupees). It may be concluded that the Azikheli buffalo is an asset for the people of northern Pakistan, providing livelihood support through the sale of milk and animals. The farmer income may be further enhanced through good feeding practices.

Keywords: Azikheli buffalo, phenotypic characteristics, body coat, entrepreneurship.

INTRODUCTION

Pakistan has a large livestock population, and well adapted to the local environment, and has some of the world best buffalo (*Bubalus bubalis*) breeds. According to the economic survey of Pakistan 2022-23, there are more than 45 million buffalo in the country (GOP 2022-23), which puts Pakistan second largest population after India (109.85 million). According to the previously reported study conducted by Borghese (2007), the buffalo breeds of Pakistan belong to the river type

with a total of 50 characteristic chromosomes. The famous local buffalo breeds of Pakistan are Nili-Ravi and Kundi and contribute 63 % to the total buffalo population of the country, whereas 37% of the buffalo population are non-descriptive breed (Khan et al., 2022) and non-descript breeds also include Azikheli, which are known for its adaptation to the hilly and harsh environment, convert low quality feed to high nutritious products (Kohler-Rollefson et al., 2009; Khan et al., 2022). Unfortunately, many indigenous breeds are on endanger of extinction because of

underestimation of the local government, ignorance of animal scientists, and improper breeding policies and technology (cross-breeding) in the country (Kohler-Rollefson et al., 2009). Furthermore, lack of proper documentation in the livestock sector and awareness among the farmers are the key reasons (Hussain et al., 2017).

Azikheli Buffalo breed is one the most underestimated buffalo breed in Pakistan, which have a unique adaptation, productive and reproductive features, and morphometric and phenotypic characteristics compared to other buffalo breeds of the country and probably in the world. Therefore, this precious breed is localized and restricted to the northern part of the country, the Malakand division, and especially to district Swat (Khan et al., 2022). This breed was first included in the livestock census in 2006, and the estimated population of the Azikheli buffalo breed was 2.9 % of the total buffalo population of the country (1.08 million). Recently the population of this breed reduced drastically because of destructive earth quake in the locality (2005), continuous war crises in the district Swat (2007-09), and further reduced by a destructive flood in July 2010. According to a baseline survey conducted by International Livestock Research Institute (ILRI) in 2017, the population of Azikheli buffalo ranged from 0.40 to 0.50 million.

Unfortunately, In Pakistan, to date, there has been no systemic research study conducted by the researcher on the economic and productive traits, phenotypic traits, and body morphometric of the Azikheli buffalo breed of Pakistan (Khan, et al., 2022). There is very limited data available on the Azikheli buffalo breed. Moreover, these data are either collected outside of the breed main hub in a survey or the trial were conducted on the impure breed of Azikheli buffalo in other parts of the country (Khan et al., 2022). Based on the limitation mentioned above, for the first time in the history of Pakistan, a very systemic 3 years long study was conducted

by the research team of the International Livestock Research Institute under four phases: i) farmers awareness programs; ii) first-ever Azikheli buffalo census; iii) and milk/beauty competition show of the Azikheli dairy buffaloes breed in Swat and finally iv) Research trials. The study main aim was to illuminate the economic and productive traits and phenotypic and morphometric parameters of the Azikheli buffaloes bred in the Swat district under traditional management conditions.

MATERIALS AND METHODS

Study Area

The current study was conducted in the whole Malakand division and especially in the district swat of Khyber Pakhtunkhwa, the northwestern province of Pakistan, located at 35.2°N, 72.4°E after completion of the first three different phases: i) farmers awareness programs; ii) first-ever Azikheli buffalo census; iii) and milk/beauty competition show of the Azikheli dairy buffaloes breed in Swat. In the study first phase, several farmer awareness programs were conducted in the Malakand division in the farmer communities regarding the Azikheli buffalo breed and buffalo census. In the second phase, a baseline census was conducted by an International Livestock Research Institute (ILRI) researcher (30) in the whole division and district swat for 6 months. Furthermore, the first-ever milk/beauty competition show of the Azikheli dairy buffaloes breed was conducted, and more than 2000 farmers, including pure buffaloes, participated in the show. According to the baseline census survey (ILRI, 2017), 95 % of the Azikheli buffalo are in district swat. The rest of the 5 % buffalo are found in the adjacent districts (Shangla, Dir, Buner, Malakand, Mardan, Charsada, and Hazara division).

Moreover, in Swat, 80-90 % of the buffalo are reared in tehsil KhwazaKhela, known as the Azikhel tribe, in 32 villages. The name of Azikheli buffalo is given due

to the Azikhel tribe in tehsil KhwazaKhela, which is the hometown of this breed. Other local names of Azikheli breed are Watanai, Malkai, and Swatai. KhwazaKhela tehsil is situated in district Swat, which is 200 km toward the northwestern capital city of Islamabad (Figure 1). The average temperature of the KhwazaKhela is 18.1°C and ranges (from -1 to 32°C) with a rainfall of 929mm (Climate Data.org" 2017).

For a phenotypic study total of 1200 Pure Azikheli Buffaloes (1000

lactating females: 200 breeding bulls) were randomly selected from these 1400 householders of the whole division (Photo 1 and 2). In the phenotypic study, the data were recorded for (Village name, farmer name, and Animal ID/Code, Age, Sex, spots, tail and horn shape recorded in a well-designed questionnaire in each animal's shed. The physical characteristic of the buffalo includes the color of the body, muzzle, eyelid, eye, hoof, horn, forehead, legs, and tail color (tail switch) were measured visually.



Figure 1: The blue area in the right middle of the map indicates KhwazaKhela, Swat map. Copied from google Maps.

In the second phase of the study, further, 400 lactating pure Azikheli buffaloes were selected from a total of 1400 householders for milk production and composition. Pool milk samples of morning and evening milk were taken after cleaning and disinfection of teats and

discharging the first few streams. Milk samples were collected in 100 ml sterile plastic vials at weekly intervals throughout the experiment and transported to the laboratory of Veterinary Research and Disease Investigation Center (VR &DIC) Balogram, Swat for analysis.



Photo 1: Pure Azikheli Buffalo KhwazaKhela Swat (Photo credit: Dr. Nadar Khan, Scientist ILRI)



Photo 2: Pure Azikheli Buffalo Bull (Photo credit: Dr. Nadar Khan, Scientist ILRI).



Photo 3: Body measurements of Pure Azikheli buffalo bull in Swat KhwazaKhela

The samples were analyzed for milk fats, proteins, lactose, ash, solid not fats (SNF), total solids, and somatic cell count (Lactoscan SA60-Milkotronic limited, Nova Zagora, Bulgaria) and microscopic examination.

In the third phase of the research study, 1200 Pure Azikheli Buffaloes (1000 lactating females: 200 breeding bulls) were randomly selected from these 1400 householders. The major body measurements were body weight, body height, body girth, body length, tail length, horn, ear, rump, hock, neck length, and width (Photo 3).

Statistical Analysis

The data were analyzed for comparison of the different traits among the male and female buffalo, with mean slandered error measured. In contrast, the least squares mean for body measurement traits.

RESULTS

Phenotypic Characteristics of Azikheli Buffaloes

Azikheli buffalo breed is a unique breed among the buffalo breed of the world. Azikheli buffalo breed is a compact small body and unique body color which attract the farmers.

The phenotypic data were measured in 1200 pure buffalo selected from 1400 householders having adult Azikheli buffalo breed (male and female). The phenotypic characteristics of the Azikheli buffalo breed are summarized in Table 1. The results reveal that a large variation ($P < 0.05$) was found in the color of different body parts in males (M) and females (F). The results showed that the bull buffalo had a high percentage of golden yellow/light brown color than the female (81: 73), followed by dark brown (blackish), albino white, and spotted (brown and white) color (Photo 4).



Photo 4: Body color variation in Azikheli Buffalo (Photo credit: Dr. Nadar Khan, Scientist ILRI)

Table 1: Phenotypic characteristics of Azikheli buffalo breed.

BODY PARTS	COLOR	FEMALE No's: 1000	MALE No's; 200	P- VALUE
Body coat	Golden yellow /Brown	73	81	< 0.05
	White albino	11	04	
	Grayish black	09	11	
	Spotted coat	07	03	
Forehead	White	75	65	< 0.05
	Spotted	17	15	
	White extended to nose	08	20	
Muzzle	White Pinkish	81	85	> 0.05
	Gray	08	03	
	Black	04	04	
	Pigmented/spotted	07	08	
Horns	White-spotted	10	15	< 0.05
	Grayish black	55	70	
	Brown	27	12	
	Completely black	08	03	
Horn Shape	Sickle	65	45	< 0.05
	Semi sickle	30	54	
	Curled	05	01	
Eyes	Gray	10	07	> 0.05
	Blue	60	57	
	Black	30	36	
Tail switch	White	15	10	> 0.05
	Brown	78	85	
	Black	08	05	
Legs (below hock joint)	Body coat color	08	12	< 0.05
	White	70	56	
	Gray	03	07	
	Black and white	19	27	

Note: The data were recorded on visual observation of each animal in an open area on sunny days by high experts from the Livestock department of the country.

The male was mostly brownish than the female, and a high percentage of albinos was observed in the female. The maximum percentage of forehead color was found to be white with very few spotted and extended to the nose in both males and females. Animals were shiny black and blue eyes. The neck of the male was short and thick in size compared to the female. The switch tail was straight and often brown >70 %, followed by white in both sexes. The animal horns were mostly sickle to semi-sickle in shape and grayish-black. Both hind and fore legs were of the same color, although the legs below the knee were pink and white.

Morphometric Characteristics of Azikheli Buffalo

The results for the morphometric characteristics of the Azikheli buffalo breed are summarized in Table 2 and

Table 2. Morphometric characteristic measurement of pure Azikheli buffalo breed selected from 1400 households in KhwazaKhela Tehsil Swat.

Parameter measured	Female (5-7 years) No's. 1000	Male (3-6 years) No's. 200	P-Value
Live body weight (kg)	440±30	410±20	P<0.05
Measurements (cm)			
Body length	140.5±1.3	133.3±1.7	P<0.05
Chest/ heart girth	183.7±3.2	170.2±2.5	P<0.05
Height at wither	127.5±0.3	133.5±0.7	P<0.05
Height below hock	47.0±0.5	50.2±0.7	P>0.05
Height at hip	121.7±0.9	127.1±1.8	P<0.05
Neck length	44.0±1.3	41.6±1.5	P<0.05
Face length	49.4±2.1	52.0±1.8	P>0.05
Ear length	22.8±1.2	23.3±0.8	P>0.05
Horn length	39.0±2.3	34.8±1.7	P<0.05
Horn root	21.5±1.6	28.0±0.8	P<0.05
Horn circumstanes	19.80±1.2	22.0±0.5	P>0.05
Tail length	65.2±2.3	59.8±2.4	P<0.05

Table 3. Milk composition of Azikheli buffalo breed in the northern Khyber Pakhtunkhwa

Traits	Minimum	Maximum	Mean
Milk yield (liter)/day	5.0	16.0	7.80
Milk composition (g/100gm)			
Fats	6.50	9.50	7.80
SNF (<i>solid, not fats</i>)	8.90	9.90	9.10
Lactose	4.75	4.95	4.85
Protein	3.30	3.65	3.50
Ash	0.70	0.95	0.85
Total solid	16.3	19.8	17.5

Photo 4. There has a large variation ($P < 0.05$) in the live body weight (LBW) of the female and male buffalo breed (440 vs. 410 kg). The female buffalo were heavier than the male buffalo, with an average of 440 kg. The LBW of female buffalo ranged (from 380 to 570 kg) from lightweight to very heavy LBW. The body length has also variable among the males and females, and females were the highest value (140.5 cm) body length than males (133.3 cm). The female buffalo was the highest value of heart girth (183.7 cm) than the male (170.2 cm). The male had the highest height value at wither (133.5 cm) than the female (127.5 cm). The neck in males was short than in females (41.6 vs. 44.0 cm). Horn was found to be short in males (34.8 cm) than in females (39.0 cm), but the root of the horn in males was found high (28.0 cm) than in females horn root (21.5 cm).



Photo 4: Morphometric traits of Azikheli Buffalo (Photo credit: Dr. Nadar Khan, Scientist ILRI).

Table 4: Economic traits of Azikheli Buffalo, bull, and milk per liter in Pakistani rupees

Economic traits	Minimum	Maximum	Mean
Milking buffalo (PKR)	300,000	400,000	350,000
Bull Price (PKR)	150,000	250,000	200,000
Milk Price/liter (PKR)	230	270	250

Note: These values are of the local market of Azikheli buffalo in KhwazaKhela Tehsil Swat in Pkr.

The tail of the female buffalo was higher (65.2 cm) in length than the male (59.8 cm) and straight in shape. There was no difference ($P > 0.05$) recorded for the ear length, hock circumstances, and facial length, although numerical variation was summarized in Table 2.

Milk Production and Composition of Azikheli Buffalo Breed

Milk production and composition of Azikheli buffalo are summarized in Table 3. The maximum and minimum milk yield per day was recorded as 16 vs. 5 liters with a mean of 7.80 liters/day. The mean milk fats value was 7.80 g/100 g,

with the maximum milk fats recorded in the current study was 9.50 g/100 g, and the lowest value being 6.50 g/100 g.

Similarly, the milk lactose value ranges from 4.74 to 4.95 g/100 g, with a mean value of 4.85. The Protein means the value was 3.50 with a range of 3.30 to 3.65 g/100 g.

Economic Traits of Azikheli Buffalo Breed

Azikheli buffalo are famous for high milk fats in northern Khyber Pakhtunkhwa. The major use of milk in the local area is tea making, and thus, the farmer's community prefers to keep at least

one Azikheli buffalo in the shed. Due to the high milk fats contents of Azikheli buffalo, the milk price is the most expensive in the province and country, and the mean price per liter is 250 pkr. There is a high variation in the market price of male and female buffalo, and the mean data are summarized in Table 4. According to the local markets, the price of lactating Azikheli Buffalo ranges from (300,000 to 400,000) with a mean value of (350,000) in PKR. The bulls are low in price, and the mean value is (200,000 pkr).

DISCUSSION

Azikheli buffaloes are docile, with a small compact body, semi-sickle horns, and short tails, and are unique in color among all the buffalo breeds of the country and the globe. Color variations were very pronounced, with most of the buffalos having a golden yellow color, with a few white albino, grayish and spotted coats also seen. Farmers prefer the golden yellowish color, whereas spots on the body are undesirable characteristics. There is very minute variation in the body color of males and females. It might be due to natural breeding with pure bulls (Seo et al., 2007). These color variations also occur due to intensive farming. Those buffalo kept for a long time inside closed sheds turn into white albinos (Parsad, 2004; Khan et al., 2022). In comparison to the Pakistani buffalo breed, Nili Ravi, Kunde, and Murrah breed of India, body coat color is black with a few are brown (Rezende et al., 2017, Khan et al., 2005), and body colors of the world buffaloes breed, including the Swamp, and riverine buffalo, are black to grey, (Miao et al., 2010, Soysal et al., 2007). Might the dark color of the buffalo breed can help them with heat intolerance due to its absorption capacity of solar radiation (Marai and Haebe, 2010).

There were spots also seen in a few buffalos, which were bad characteristics according to the farmers. Azikheli buffalo have a short tail as compared to Nili Ravi

and Kundi. The udder is closely attached to the body. Horns are semi-sickle in shape and grayish like other Mediterranean animals (Khan et al., 2007). Farmers prefer unspotted and healthy buffalo with huge udder, semi-skell-shaped horns, and lengthy wedge bodies (Khan et al., 2019).

Morphological information is crucial for future animal conservation, genetic resources, and breed improvement strategies (Mirza *et al.*, 2015). To our knowledge and being a native of this breed, to date, there has been no systematic research study conducted on the Morphological parameters of the Azikheli buffalo breed. Although some researchers conducted 1, 2 studies, it was either in the form of a survey or out of the home tract on the impure breed. The body length of Azikheli was less (133-140 cm) than both Nili Ravi (145-149 cm) and Kundi (159-165 cm) buffalo. Contrary to the Nili Ravi and Kundi, the Azikheli bulls are slightly shorter (133.3 cm) in body length than females (140.5 cm). Height at wither in Azikheli buffalo (127- 133 cm) is also less than Nili Ravi (125- 135 cm) and Kundi breed (135 – 137 cm). Azikheli Bulls are slightly high at height (133 cm) at wither than female buffalo (127 cm). This small body of Azikheli buffalo supports less amount of feed requirements, has an excellent conversion of low-quality roughages, is highly adaptable to fodder fluctuation, is adaptable to hilly areas, and high reproductive efficiency than other buffalo breeds (Ahmad et al., 2013), and can move more easily and rapidly on mountain slopes (Khan et al., 2019).

Likewise, Nili Ravi and Kundi buffalo breeds and Azikheli buffalo breeds are excellent milk producers (Khan, 1994; Khan et al., 2022). In the current study, Azikheli buffalo were highly variable in milk production (5-16 liters/day) with an average of 7.8/day. The variation in milk yield was mainly due to insufficient quality fodder, lack of concentrate feeding, poor management, and seasonal variation. The effect on milk production was

supported by early studies (Uddin et al., 2016; Afzal et al., 2007). Animals were stalled fed with natural grasses, wheat straw, maize fodder, and wheat bread and provision one to two times of drinking water. In 2017, in the first-ever Azikheli buffalo milk and beauty competition held in the home tract of Azikheli buffalo, the high milk per day was recorded at 23 liters a day and 31 liters per 3-time milking (Khan et al., 2019).

The Azikheli buffalo breed is famous for its high milk fats and lactose percentage compared to other Pakistani buffalo breeds and probably in the world. The maximum milk fats have given this breed a unique quality and high market value. The average milk fats % in the Pakistani breed is around 6.0 g/100 g (Sun et al., 2014), which is very low than the Azikheli buffalo, with an average of 7.8 g/100 g. The high fats might be due to its genetic characteristics and dry forages feeding, which is the major portion of the ration round the year (Yadav et al., 2013; Zhou et al., 2018). The pure Azikheli buffalo breed is very expensive and rarely available for sale. The high market price of the Azikheli buffalo might be due to its unique color traits and high milk fats contents which make milk prices very high compared to other buffalo breed milk in the country.

CONCLUSION

It was concluded that the Azikheli buffalo has a small body with docile nature, a unique body color of golden yellow, semi sickle horn, and a short tail, which make farmers more attractive than any other breed in the local area. Azikheli buffalo are comparable in production with high milk fats to other buffalo breeds of Pakistan. The farmers income may be further enhanced through good practices in genetic improvement and feeding management. Moreover, the population of this unique breed is decreasing drastically due to cross-breeding and improper ways

of insemination in recent years. Therefore, it is recommended that an urgent need to define strategies to prioritize breed conservation. However, effective strategies or conservation schemes for this valuable breed should be conceived and implemented. It is also recommended that the animals should spread in other northern parts of the country having the same climate, including Gilgit Baltistan Hazara division and Azad Jammu Kashmir.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

REFERENCES

- Afzal M, Anwar M, Mirza M (2007). Some factors affecting milk yield and lactation length in Nili Ravi buffaloes. *Pak Vet J.*, 27:113-117.
- Ahmad N, Muhammad A, Khalid J, Muhammad S. K, Muhammad K B, Younas U, Nasrullah (2013). Relationship between body measurements and milk production in Nili Ravi buffaloes maintained at commercial farms in peri-urban

- Vicinity of Lahore. Buffalo Bulletin., 32:792-795.
- Borghese A. (2007). Buffalo Production and Research. FAO Rome.
- Government of Pakistan (GOP) (2022). Pakistan Economic Survey. Ministry of Finance. Available online at: www.finance.gov.pk (July, 2022).
- Khan N, Sami K, Muhammad I, Mian G H, Muhammad N M I, Nazir A K (2022). Comparing Azikheli buffaloes with Nili Ravi buffaloes for morphometry, productivity, and reproductivity. *Pak J of Agric Sci.*, 59: 693-701.
- Khan B B, Younas M, Muhammad R, Muhammad Y (2005). Breeds of Livestock in Pakistan. Department of Livestock Management, University of Agriculture, Faisalabad, Pakistan, pp. 2–6.
- Khan S M, Khan M, Sohail, Mahmood S (2007). Continuing education article genetic resources and diversity in Pakistani sheep. *Int J of Agric Bio.*, 6:941-944.
- Khan N, Muhammad N M I, Muhammad S Q (2019). Evaluation of breed parameters and entrepreneurship traits of Azikheli buffalo in Swat. *Inter Buffalo Congress (Abstract)*.
- Khan U (1994). Review on buffalo research and development activities in Pakistan: past performance and future strategies. *Asian Livestock (FAO)*.
- Köhler I, Rathore H S, Mathias E (2009). Local breeds, livelihoods, and livestock keepers' rights in South Asia. *Trop Ani Health Prod.*, 41:1061-1071.
- Marai I F M, Haebe M A (2010). Buffalo biological functions as affected by heat stress: a review. *Liv Sci.*, 127:89–109.
- Miao Y, Wu G, Wang L, Li D, Tang S, Liang J, Mao H, Luo H, Zhang H (2010). The role of MC1R gene in buffalo coat color. *Sci China Life Sci.*, 53:267–272.
- Mirza R, Khalid J, Muhammad A, Muhammad R, Dilshad S, Khan M, Tipu M (2015). Genetic and phenotypic correlation of body measurements with milk yield in Nili Ravi buffaloes of Pakistan. *Jour of Ani Health and Prod.* 3:1-5.
- Parsad R B (2004). Phenotypic Characteristics of the Tarai Buffalo breed. *World Buffalo Cong.*, 20-23 Oct 2004, Makati City, Philippines., 136-138.
- Rezende M P, Ferraz G D, Carneiro P L S, Malhado M G (2017). Phenotypic diversity in buffalo cows of the Jafarabadi, Murrah, and Mediterranean breeds. *Pesquisa Agropecuária Brasileira*, 52:663-669.
- Seo K, Mohanty R T, Choi T, Hwang I (2007). Biology of epidermal and hair pigmentation in cattle: a mini review. *Vet Dermat.*, 18:392–400.
- Soysal M I, Tuna Y T, Gurcan E K, Ozkan E, Kok S, Castellano N, Cobanoglu O, Barone C M A (2007). Anatolian water buffaloes husbandry in Turkey: preliminary results on somatic characterization. *Ital J of Ani Sci.*, 6:1302–1307.
- Sun Q, Lv J P, Liu L, Zhang S W, Liang X, Lu J (2014). Comparison of milk samples collected from some buffalo breeds and crossbreeds in China. *J of Dai Sci and Tech.*, 94:387-395.
- Uddin M, Minto A, Awal T, Kondo M, Abdul K (2016). Characterization of buffalo milk production system in Bangladesh. *Bang J of Ani Sci.*, 45: 69-77.
- Yadav, S, Sikka P, Kumar S S D, Pandey A, Yadav P, Sethi R (2013). Variation in milk constituents during different parity and seasons in Murrah buffaloes.
- Zhou L, Tang Q, Muhammad W I, Xia Z, Huang F, Li L, Liang M, Lin B,

Khan et al., (2023). Comprehensive Assessment of Azikheli Buffalo Breed of Pakistan.
J Biores Manag., 10(4):95-106.

Qin G, Zou C (2018). A comparison of milk protein, fat, lactose, total solids, and amino acid

profiles of three different buffalo breeds in Guangxi, China. *Ital J of Ani Sci.*, 17:873-878.