Developing a new selection index for the Italian Mediterranean Buffalo (*Bubalus bubalis*)

R. Negrini[1], S. Biffani[2], M. Fioretti[1], R. Cimmino[3] and M. Gómez[3]

[1]Italian National Breeders Association (AIA), Rome, Italy
Consiglio Nazionale delle Ricerche (CNR), Istituto di biologia e biotecnologia agraria (IBBA) 20133 Milano, Italy
[3]Italian National Association of Buffalo Breeders, Caserta, Italy
Corresponding author: biffani@ibba.cnr.it

Abstract

The breeding of the Mediteranean buffalo is a long-standing Italian tradition, being internationally recognized thanks to its iconic *Mozzarella di Bufala Campana*, a Protected Designation of Origin (PDO) certified mozzarella cheese. Over a population of more than 419.000 extant animals, the Italian National Association of Buffalo Breeders (ANASB) involved 121.403 animals from 380 farms mainly widespread in central and southern areas of the country. In 2019, official milk recording by certified recorders belonging to the Associazione Italiana Allevatori (AIA) and following the ICAR guidelines included 49.932 buffalo cows in 215 herds. In 1997 a first selection scheme was implemented. It was based on a traditional progeny testing and a BLUP genetic evaluation of milk productive traits. A first selection index, namely the PKM, was also developed. The breeding objective of the PKM was the mozzarella cheese yield using as selection criteria milk yield, fat and protein. Although a positive selection on milk yields was observed from 1.608 Kg in 1977 to 2.169 Kg in 2018, PKM had an unfavorable effect on the genetic trend for fat and protein.

In order to recover the unfavorable trend of milk components as well as to include morphology, a new selection index named IBMI has been developed and applied since 2019. The IBMI breeding objectives are milk production and mozzarella yield. IBMI includes five selection criteria: feet and legs, udder morphology, milk kilograms, fat and protein percentage whose relative emphasis was 24, 20, 21, 15 e 20, respectively. The expected genetic progress by generation using IBMI is +58 Kg for milk, +0.10 and 0.05 % respectively for fat and protein percentage. The next steps in the selective activity will be: a) the development of a test day model for productive traits and b) the implementation of a single step genomic EBV evaluation.

Keywords: Buffalo, genetic response, selection index.

Introduction

The Water Buffalo (*Bubalus bubalis*) is a large bovid mainly distributed in the Asian continent where the 97% of its world population is concentrated (FAO, 2020). The name 'water buffalo' is due to its adaptation to flooded or swampy areas, where it partially submerges and walks on the bottom mud without difficulty. The Mediterranean area, where the rest of the world population is raised (3%), historically have been characterized by these optimal rearing conditions. In the European continent can be found only the 0.2% of its world population and about 93% of these animals can be found in south-central Italy (Neglia *et al*, 2020). Total census in Italy increased considerably, making it one of the most important dairy species in the country. In 2019, 34,990 lactating buffaloes have been registered to the herd book. Moreover, 666,960 controlled lactations and 9,953 type traits evaluations are available and officially recorded (ANASB, 2020). Thanks to the physical-chemical properties of its milk - high concentration in protein and fat (FC ~ 8 %) and favorable coagulation (Costa *et al*, 2020) the main zootechnical interest of the Italian Mediterranean Buffalo (IMB) is to produce iconic traditional dairy products like the *Mozzarella di Bufala Campana* (Boselli *et al*, 2020), that has a great economic impact on the Italian food industry (ISMEA, 2020). Costa *et al.* (2020a, 2020b) refers to the impressive increase in heads that the IMB has experienced in the last 15 years, with an increase in terms of kilos of cheese produced, a larger herd size, a constant increase in registered herds, as well as the rise in milk price. Therefore, the economic interest in this specie makes it necessary to develop new innovative tool to improve breeding process. In 1997 a first national selection scheme was implemented. It was based on a traditional progeny testing and a BLUP genetic evaluation of milk productive traits. A first selection index, namely the PKM, was also developed. The breeding objective of the PKM was the mozzarella cheese yield using as selection criteria milk yield, fat and protein (Rosati and van Vleck, 2002). Although a positive selection on milk yields was observed– from 1.608 Kg in 1977 to 2.169 Kg in 2018, PKM had an unfavorable effect on the genetic trend for fat and protein. Moreover, no emphasis was given to health related or functional traits. An effective breeding objective should be defined for the genetic improvement of any population such that the future individuals, e.g., buffalo cows, will produce the desired products more efficiently under expected future economic production environment (Lopez-Villalobos and Garrick, 2005). Attending to mozzarella cheese manufacturers and farmers community, who both asked for a more balanced breeding objective which included also health related traits, annual genetic response for milk yield (MY), milk components (MC), composite feet and legs (FL) and mammary system (MS) and their correlated response with mozzarella cheese production were estimated in the IMB using selection index theory to eventually develop a new and more up-to-date aggregate selection index.

Material and methods

Different selection indices (I) and breeding objectives (H) were constructed using selection index theory (Hazel,1943).

The selection indices investigated in this study considered the following traits: MY, fat content (F%), protein content (P%), mozzarella cheese production (MCY) estimated as 116.615 + 2.015 * (P% * F%) + 2.929 x $(P\%)^2$, and two composite traits FL and MS. The indices were of the form

$$I = b_1\, x_1 + b_2 x_2 + \ldots + b_m\, x_m = \mathbf{b'x}$$

where x_i is an observation on the *ith* trait and b_i is the selection index coefficient (or weight) for that trait. In vector notation, $b' = [b_1, b_2, \ldots, b_m]$ and $x' = [x_1, x_2, \ldots, x_m]$.

Three alternative breeding objectives were formulated according to relative weights given to MY, MCY, FL and MS. The different breeding objectives and relative weights considered in this work are shown in Table 1

The three scenarios were formulated in order to give an increasing relative emphasis on milk yield, but keeping the emphasis to MCY above 30%. The breeding objectives were of the form

$$H = w_1\, g_1 + w_2\, g_1 + \ldots + w_m\, g_1 = w'\, g$$

where g_i is the additive genetic value of the *ith* trait and x_i is the relative economic emphasis of the trait. In vector notation, $w'=[w_1, w_2, \ldots, w_m]$ and $g'=[g_1, g_1, \ldots, g_m]$. The vector **b** was derived from the equation $\mathbf{b = P^{-1}Ga}$

where **P** is the *n x n* phenotypic variance–covariance matrix of the traits (*n*) used as selection index, and **G** is the n *x m* genetic covariance matrix between traits in selection index (*n*) and traits in the aggregate genotype (*m*).

Matrices **P** and **G** were estimated using data from 7199 buffalo cows and a pedigree including 19574 buffalos. A multi-trait animal model was fitted using a Bayesian implementation via Gibbs sampling.

Genetic response (**GR**) to selection for each trait considered in the selection indices was calculated with a deterministic procedure (Cameron, 1997) applying the equation

$$GR_j = \frac{b' G_j}{\sqrt{b^i P b}}$$

where $\mathbf{GR}_j$ is the **GR** for trait *j* and $\mathbf{G}_j$ is the *jth* column of matrix G.

Results and discussions

The genetic correlation among the breeding goals and the selection criteria used to estimate the response to selection for the three different breeding scenarios are in Table 2

Mozzarella cheese production had an unfavourable genetic correlation with MY (- 0.54), a null correlation with MS (-0.01), and a favourable correlation with FL (0.25), F% (0.87) and P% (0.96). correlation. Those values had an impact on the selection response for all traits considered in the three scenarios which are shown in Table 3.

The breeding objective S1 showed large and positive genetic response in terms of mozzarella cheese production, fat and protein %. However, MY was strongly penalized, with a negative genetic response. The breeding objective S2 had the best results for health related traits, namely feet and legs and mammary system. In this scenario, 35% of the relative emphasis in the breeding objective was given to health related traits. The last scenario - S3 - showed the best overall results with a positive genetic response for all traits included in the breeding objective ranging from 0.02 (MYC) to 0.21 (P%). The scenario S3 was eventually chosen as the official new selection index for the IMB, called IBMI.

Selection index combines different sources of information that can be used to predict an animals' breeding value. It combines this information by weighting it with its relative importance based on the relationship with the breeding goal. In the IMB the breeding goals were identified as: Cheese Production, Milk Yield and Longevity. The need for a change was mainly based on a frankly discussion among ANASB technicians, farmers and cheese makers. The observed negative genetic trend for fat and protein content suggested the need for a substantial change. From one side there was the need to keep increasing the kg of milk but at the same time there was the urgency of recovering the fat and protein content negative genetic trend. Moreover, the farmers asked for including some linear traits, especially the ones related to longevity and health (e.g., udder and feet and legs). Indeed, the new breeding goal gives more emphasis to the cheese production and at the same time increases milk yield, looking for the first time at the functional morphology.

Table 1. Relative emphasis (%) on traits included in alternative breeding scenario for the IMB.

	Traits in breeding objective[s]			
Breeding scenario	MY	MCY	FL	MS
S1	5	45	30	20
S2	30	35	15	20
S3	45	45	5	5

Table 2. Estimates of genetic correlations among the breeding goals and the selection criteria in the IMB.

Traits	FL[a]	MS[a]	MY[a]	F%	P%	MCY[a]
FL	1.00	0.19	0.00	0.15	0.28	0.25
MS	0.19	1.00	0.29	- 0.08	0.03	-0.01
MY	0.00	0.29	1.00	-0.55	-0.47	-0.54
F%	0.15	-0.08	-0.55	1.00	0.69	0.87
P%	0.28	0.03	-0.47	0.69	1.00	0.96
MCY	0.25	-0.01	-0.54	0.87	0.96	1.00

[a] Traits in the breeding objectives.

Table 3. Genetic response (expressed in genetic standard deviations) for the three breeding objective.

	Traits[b]					
Breeding scenario[a]	MY	MYC	P%	F%	FL	MS
S1	-0.24	0.05	0.42	0.32	0.14	0.13
S2	0.03	0.03	0.25	0.15	0.16	0.22
S3	0.11	0.02	0.21	0.12	0.14	0.20

[a] relative weight given to MY, cheese production, FL and MS: 5:45:30:20 (S1), 30:35:15:20 (S2) and 45:45:5:5 (S3)
[b] MY = Milk yield (kg/270d), MYC = mozzarella cheese production (MCY) estimated as 116.615 + 2.015 * (P% * F%) + 2.929 x $(P\%)^2$, P% = protein %, F% = fat 5, FL = composite feet and legs, MS = composite Mammary System

Conclusions

The new selection index for the Italian Mediterranean buffalo (IBMI) is extremely different from the former selection index (PKM). Introducing it as a new selection tool has actually been a cornerstone of buffalo breeding in Italy, affecting bulls and dam rankings. Indeed, the best individuals are no longer those with the highest milk EBV, but those that best match the need for a more balanced breeding objective (production, quality and functionality). Moreover, changing the breeder's attitude to look at only one trait, milk production, is not *as easy as pie*. It takes time and needs the right piece of information.

The IBMI is the very first attempt to use selection index theory to set up an aggregate index in the Italian Mediterranean buffalo. However, it can be adjusted especially as concerns the phenotypes used to improve the quality of milk for mozzarella cheese production. In the present research, fat and protein percentage were used as proxies of milk quality but several studies have already showed that milk coagulation properties like rennet coagulation time or curd firmness 30 min after coagulant addition are important traits for enhancing the efficiency of the dairy industry.

Those new phenotypes coupled with the use of genomic selection are the on-going and very next ANASB breeding objectives.

List of references

ANASB, 2020, (Associazione Nazionale Allevatori Specie Bufalina). *http://www.anasb.it/statistiche/* [Accessed May 11, 2020].

Boselli C, De Marchi M, Costa A, Borghese A. 2020 Study of Milkability and Its Relation With Milk Yield and Somatic Cell in Mediterranean Italian Water Buffalo. Front Vet Sci 7(432):432. doi: 10.3389/fvets.2020.00432.

Cameron, N.D., 1997. Selection Indices and Prediction of Genetic Merit in Animal Breeding. CAB International, Wallingford, UK.

Costa A, Neglia G, Campanile G, De Marchi M. 2020b Milk somatic cell count and its relationship with milk yield and quality traits in Italian water buffaloes. J Dairy Sci 103(6):5485-94. doi: 10.3168/jds.2019-18009.

Costa A, Negrini R, De Marchi M, Campanile G, Neglia G. 2020a Phenotypic Characterization of Milk Yield and Quality Traits in a Large Population of Water Buffaloes. Animals 10(2):327. doi: 10.3390/ani10020327.

Food and Agriculture Organization (FAO). 2020. Live Animals. Available online at: http://www.fao.org/faostat/en/#data/QA [Accessed September 28, 2020).

Hazel, L.N., 1943. The genetic basis for constructing selection indexes. Genetics 28, 476–490.

ISMEA. 2020. *http://www.ismeamercati.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/5186* [Accessed Sept 15, 2020].

Lopez-Villalobos, N.,Garrick,D.J., 2005.Methodology for the design and enhancement of genetic improvement programs illustrated in the context of the New Zealand dairy industry. Agrociencia IX, 553–568.

Neglia G, de Nicola D, Esposito L, Salzano A, D'Occhio MJ, Fatone G. 2020. Reproductive management in buffalo by artificial insemination. Theriogenology 150:166-72. doi: 10.1016/j.theriogenology.2020.01.016.

Rosati A and Van Vleck L.D. 2002 Estimation of genetic parameters for milk. fat. protein and mozzarella cheese production in Italian river buffalo population. Livestock Prod Sci 74:185-190.