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The impact of crossbreeding Egyptian and Italian buffalo on milk yield and composition under subtropical environmental conditions

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Buffalo are the second most valuable species in the world for milk production and their milk prices have been based on fat and protein composition. The aim of the paper was to compare the milk yield and composition of pure Egyptian buffalo (EB) and their crosses with the Italian buffalo and to investigate the impact of temperature humidity index (THI) on milk yield and composition under subtropical stressful conditions. 516 lactating buffalo were used (152 EB; 176 F_1 crosses 50% EB and 50% Italian buffalo and 188 back cross (BC) 75% EB and 25% Italian buffalo). The results revealed that, milk yield (5·79 and 10·32%) and peak yield (6·36 and 7·67%) were significantly higher in F_1 and BC than in EB, respectively. BC had 7·74 and 3·67% significantly higher daily yield when compared with EB and F_1, respectively. EB were robust in the hot condition as the only reduction was in the peak of milk production from 15·02 in low THI to 13·72 kg in high THI, but fat and total solids%, were increased from 5·61 and 16·31 THI in low to 7·01 and 17·59 in high THI, respectively. BC was similar to some extent to EB as their milk was similar to EB under sever hot climate conditions (2331·92 and 2327·50 kg, respectively). A statistically significant reduction in the average daily milk yields was detected only in F_1 from 10·33 to 8·38 kg in low and high THI level, respectively. The current study showed that BC produced a higher milk with higher daily average milk yield and peak yield with some evidence of robust under sever hot condition which were approximately similar to EB. Thus, it is recommended to encourage the producers to increase the number of BC animals in their farm for improving the milk production to fulfil the demand of Egyptian markets.

Keywords: Egyptian buffalo, crosses, THI, milk yield, milk composition.

The domestic water buffalo belongs to the species *Bubalus bubalis*. All European buffaloes are considered to be of the same breed, the Mediterranean, which includes those of Italy, Egypt, Greece, Bulgaria, Syria and Turkey (Han et al. 2012). Buffalo are the second most valuable species in the world for milk production (Han et al. 2012; Coroian et al. 2013). However, buffalo are low milk producers compared to the dairy cow breeds reared in Egypt, but their milk price is approximately three times that of dairy cattle (Rosati & Van Vleck, 2002). Customers are now looking for a product with desirable and efficient properties. Thus, milk prices have been based on composition and the dairy producers have altered their farming management to produce milk with high protein, fat and solids. This has increased the need for studies that aim to increase milk's valuable components without altering its industrial quality.

The Italian buffalo is considered the best in the world, it has the highest milk production and fat percentage (Varricchio et al. 2007), good genetic make-up and facilitates application of practical technologies and monitoring of hygiene, thus achieving good quality products. The consumption of buffalo milk in Egypt has increased drastically, and is currently considered the second source of milk production (45·86%, FAOSTAT, 2015). Improving buffalo milk production (i.e. quantity and quality) works as a tool for improving the quality of life especially for family farmers in charge of this animal in developing countries (Aggarwal & Upadhyay, 2013). Improving milk yield is not straightforward, as selecting for a single trait such as quantity might lead to lower milk quality and/or reproductive efficiency (Barros et al. 2014). On the other hand, the heritability estimate for milk yield was moderate, suggesting that this trait will respond to direct mass selection (Malhado et al. 2013). With this in mind producers had attempted to improve this trait, as well as reproductive traits, of their Egyptian buffaloes by crossbreeding the pure Egyptian

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buffaloes (EB) with the Italian buffaloes, using imported Italian buffalo semen with proven breeding values.

In tropical and subtropical areas, high environmental temperature, relative humidity, solar radiation and heat stress are the most crucial constraint on animal production (Marai et al. 2009). The weather in Egypt is described as moderate to high summer temperatures coupled with moderate humidity levels. Dairy cattle can be significantly affected by heat stress, and severe hot and humid weather such as that found in Egypt can affect welfare, health and survival ability as well as reproductive and productive performances (Dunn et al. 2014). Nonetheless, buffaloes have a higher ability to withstand undesirable environmental conditions and a notable longevity (approximately 10 years of production; Dunn et al. 2013). The buffalo exceeds the cow's ability to acclimatise in hot and humid regions of muddy and swampy lands. Therefore, buffaloes do well in extremely hot conditions of tropics and subtropics (Marai & Habeeb, 2010). The adaptability estimates for buffaloes *vs* Friesian cows were 89·1 and 82·9%, respectively (Marai et al. 2009). Temperature humidity index (THI) is commonly used all over the world to evaluate the consequence of temperature and relative humidity on animal performance (Akyuz et al. 2010). To our knowledge, scant and limited information is available in the literature regarding the associations among THI, milk yield and composition with different buffalo genetic types (pure Egyptian buffalo and their crosses with Italian) and the performance difference between them, especially under subtropical conditions. Therefore, this study aimed to compare the milk yield and composition of different genetic types (EB, F_1 and BC) and investigate the impact of THI on milk yield and composition under subtropical Egyptian conditions.

Materials and methods

Animals and management

This study was carried out on lactating buffalo reared by a farm in Masr-Ismallia El Sahrawy Road, Ismallia, Egypt. The herd consisted mainly of 516 lactating buffalo; 152 pure Egyptian buffalo (EB), 176 F_1 crosses (50% pure Egyptian buffalo and 50% Italian buffalo) and 188 back cross (BC; 75% pure Egyptian buffalo and 25% Italian buffalo). Buffalo were kept loose in a free-stall yard under partially roofed sheds to protect them from extremes of hot and/or cold weather. They were kept in separate pens according to their level of milk production, with free access to drinking water. All animals were fed the same mixed ration (MR 50 kg/daily). The ration was mixed daily and formulated to meet the predicted requirements of energy, protein, minerals and vitamins for reproductive status and milk yield. The MR was analysed by wet chemistry methods and its primary analysis include 12·5% crude protein, net energy for lactation (Mcal/kg = 2·4), 31% neutral detergent fiber and 19% acid detergent fiber. Buffalo were fed with Egyptian clover berseem (Trifolium alexandrinum), during December to May and Alfalfa hay during the rest of the year. Animals were machine milked three times daily at 04:00 am, 12:00 pm and 08:00 pm. Milk yields were recorded individually for each buffalo at each milking. This study was carried out under the Animal Care and Welfare Committee of Zagazig University, Egypt (ANWD-206). Milk samples of 50 ml were collected in clean sterile polypropylene containers from the three consecutive milking and pooled at the mid of lactation for determining the milk composition (fat %, protein %, total solids %, solids not fat %, ash % and lactose %) using infra-red spectroscopy (Milko-Scan 133B; N. Foss Electric, DK 3400 Hillerod, Denmark). Samples were transferred on dry ice and stored at −80 °C until analysis.

Metrological data

Temperature-humidity index (THI) has been developed as a weather safety index to monitor and decrease losses associated with heat stress. It is a distinctive value coupled the effects of air temperature and humidity. The daily ambient temperature and relative humidity in the farm area were obtained from the nearest meteorological station, approximately 37 km way. The collected data were used to estimate the maximum daily THI (Kendall & Webster, 2009) as follows:

$$\mathrm{THI} = (1{\cdot}8^{*}\mathrm{AT} + 32) - ((0{\cdot}55 - 0{\cdot}0055^{*}\mathrm{RH}) \times (1{\cdot}8^{*}\mathrm{AT} - 26)),$$

where AT = ambient temperature (°C), RH = relative humidity (%).

The monthly average temperature, relative humidity and THI varied with season as expected with maximum values between July and September and a nadir in December and January. To investigate the impact of THI on milk yield and composition, buffalo were classified according to the THI at calving day into low (months with average ≤70 THI), moderate (months with average >70 and ≤80 THI and high (months with average >80 and up to 85 THI: Gantner et al. 2011).

Statistical analysis

Statistical analysis was carried out through a generalised linear model using SAS statistical system Package (SAS, 2008). The data were normally distributed. The statistical model was adjusted for the following effects; fixed effects of THI, genetic groups and parity, while the dependent variables were milk yield (305 d), milk/d, peak of milk yield, days to attain peak yield, fat %, total protein %, total solids %, solids not fat %, lactose % and ash %, also with buffalo age as covariate. The comparison of means among the groups was performed with Duncan's multiple range tests. Values were considered significant at $P \leq 0{\cdot}05$.

Results

The effect of different genetic types on milk yield and composition

Crosses of Egyptian and Italian buffalo (25 and 50% Italian buffalo) have a significantly higher milk yield (2511·59 and 2408·48 kg, respectively) than pure Egyptian buffalo (2276·65 kg). The average daily milk yield was highest in the BC. They yielded 1·05 and 0·87 kg of milk/d more than EB and F_1, respectively. The peak of milk production was higher in both crosses (14·74, BC and 14·56, F_1 kg) when compared with the Egyptian buffalo (13·69 kg). EB had the highest significant milk fat %. They produced 0·65% more fat than that of both crosses. There was no significant difference in the days to attain peak milk production, milk protein, solid not fat, total solids, lactose and ash among the three different genetic types (Table 1).

The effect of THI on milk yield and composition

In EB, there were no significant differences in milk yield and days to attain the peak of milk yield between low (2212·63 kg and 34 d, respectively) and high (2331·92 kg and 40 d, respectively) THI (Table 2), while in F_1 milk yield and days to attain the peak of milk yield significantly decreased from 2463·83 kg and 42 d in low THI to 2255·90 kg and 36 d in high THI, respectively (Table 3). But, there was no significant difference between low and moderate THI, and between moderate and high THI in BC (Table 4). The average daily milk yield was lower only in F_1, in which decreased from 10·33 kg (low THI) to 8·38 kg (high THI) (Table 3). High THI reduced the peak milk production in the three genetic types. It decreased from 15·02 kg (low THI) to 13·72 kg (high THI); 15·24 kg (low THI) to 14·07 kg (high THI) and 15·52 kg (low THI) to 14·04 kg (high THI) in EB (Table 2), F_1 (Table 3) and BC (Table 4), respectively. Milk fat and total solids % tend to increase in the high THI when compared with the lower one in the different genetic types, while no difference was detected for the other milk composition in the different genetic types between the three THI levels.

Table 1. Effect of different Genetic types of buffalo on milk yield and composition

	Breed (genetic type)			
Traits	EB†	F_1‡	BC§	RSD¶
Milk yield (kg)	2276·65^b	2408·48^a	2511·59^a	517·20
Milk/day (kg)	9·43^b	9·80^b	10·16^a	2·11
Peak of milk yield (kg)	13·69^b	14·56^a	14·74^a	2·01
Days to attain peak yield	35·92	36·85	39·25	13·85
Fat (%)	6·70^a	6·06^b	6·05^b	2
Protein (%)	4·16	4·16	4·15	0·40
SNF (%)††	10·68	10·68	10·66	1·02
TS (%)‡‡	17·38	17·05	16·72	2·35
Lactose (%)	5·63	5·63	5·62	0·53
Ash (%)	0·87	0·87	0·87	0·08

†EB: pure Egyptian buffalo.
‡F_1: crossbred Egyptian buffalo 50% X Italian buffalo 50%.
§BC: backcross of Egyptian buffalo 75% X Italian buffalo 25%.
¶RSD: residual standard deviation.
††SNF: solid not fat.
‡‡TS: total solids.
^{a,b}Values within a row with different superscripts differ significantly.

Table 2. Effect of temperature-humidity index (THI) at calving on milk yield and composition in pure Egyptian buffalo

	Temperature-humidity index (THI)			
Traits	Low†	Moderate‡	High§	RSD¶
Milk yield (kg)	2212·63^b	2567·54^a	2331·92^b	519·66
Milk/day (kg)	9·85	10·91	9·98	2·30
Peak of milk yield (kg)	15·02^a	13·72	13·72^b	1·83
Days to attain peak yield	34·14^{ab}	30·93^b	40·43^a	14·64
Fat (%)	5·61^b	5·74^b	7·01^a	2·17
Protein (%)	4·17	4·11	4·12	0·34
SNF (%)††	10·70	10·56	10·58	0·88
TS (%)‡‡	16·31^b	16·30^b	17·59^a	2·34
Lactose (%)	5·64	5·56	5·57	0·46
Ash (%)	0·87	0·86	0·87	0·07

†Low: THI ≤ 70.
‡Moderate: THI, > 70 and ≤ 80.
§High: THI over 80.
¶RSD: residual standard deviation.
††SNF: solid not fat.
‡‡TS: total solids.
^{a,b}Values within a row with different superscripts differ significantly.

Discussion

Effect of different genetic types on milk yield and composition

The current study was conducted to assess the productive performance of the EB and their F_1 and BC crossbred, under stressful subtropical conditions in Egypt and furthermore, to compare the adaptability of the crosses to such conditions in comparison to EB. Differences in the results of milk yield and composition in different buffalo populations around the world may be due to a variety of factors including: herds' genetic makeup, size of the herds, environmental condition, managerial, hygienic-sanitary situation, feed quality, calving season and calving order (Macedo et al. 2001; Fooda et al. 2010; Araújo et al. 2012; Bhutkar et al. 2014). In the current study, the milk yield of F_1 and BC was higher than that of EB (5·79 and 10·32%, respectively) which supported the recent finding of Fooda et al. (2011) on a similar crossing. These results were compatible with the findings of others on pure Italian buffalo (Rosati & Van Vleck, 2002). This might be due to the recently efficient genetic improvement in Italian

Table 3. Effect of temperature-humidity index (THI) at calving on milk yield and composition in F_1 (50% Egyptian X 50% Italian buffalo)†

	Temperature-humidity index (THI)			
Traits	Low‡	Moderate§	High¶	RSD††
Milk yield (kg)	$2463·83^{a}$	$2598·82^{a}$	$2255·90^{b}$	516·55
Milk/day (kg)	$10·33^{a}$	$9·87^{a}$	$8·38^{b}$	1·92
Peak of milk yield (kg)	$15·24^{a}$	$14·30^{b}$	$14·07^{b}$	1·87
Days to attain peak yield	$41·98^{a}$	$33·38^{b}$	$36·21^{b}$	13·19
Fat (%)	$5·50^{b}$	$6·50^{a}$	$6·85^{a}$	1·79
Protein (%)	4·09	4·10	4·21	0·33
SNF (%)‡‡	10·51	10·52	10·81	0·85
TS (%)§§	$16·00^{b}$	$17·03^{a}$	$17·66^{a}$	2·09
Lactose (%)	5·54	5·55	5·70	0·44
Ash (%)	0·86	0·86	0·88	0·07

†F_1: crossbred Egyptian buffalo 50% X Italian buffalo 50%.
‡Low: THI ≤ 70.
§Moderate: THI, >70 and ≤80.
¶High: THI over 80.
††RSD: residual standard deviation.
‡‡SNF: solid not fat.
§§TS: total solids.
[a,b]Values within a row with different superscripts differ significantly.

Table 4. Effect of temperature-humidity index (THI) at calving on milk yield and composition in BC†

	Temperature-humidity index (THI)			
Traits	Low‡	Moderate§	High¶	RSD††
Milk yield (kg)	$2642·90^{a}$	$2498·48^{ab}$	$2327·50^{b}$	446·41
Milk/day (kg)	10·87	10·03	9·86	1·83
Peak of milk yield (kg)	$15·52^{a}$	$14·17^{b}$	$14·04^{b}$	2·06
Days to attain peak yield	$41·78^{a}$	$40·12^{a}$	$33·95^{b}$	12·32
Fat (%)	$5·05^{c}$	$6·07^{b}$	$7·50^{a}$	1·71
Protein (%)	4·16	4·22	4·16	0·48
SNF (%)‡‡	10·67	10·84	10·69	1·23
TS (%)§§	$15·72^{c}$	$16·91^{b}$	$18·19^{a}$	2·28
Lactose (%)	5·62	5·71	5·63	0·64
Ash (%)	0·87	0·89	0·88	0·10

†BC: backcross of Egyptian and Italian buffalo (25% Italian buffalo).
‡Low: THI ≤ 70.
§Moderate: THI, >70 and ≤80.
¶High: THI over 80.
††RSD: residual standard deviation.
‡‡SNF: solid not fat.
§§TS: total solids.
[a,b,c]Values within a row with different superscripts differ significantly.

buffalo and increasing their milk production (Borghese, 2005). Moreover, the milk yield from EB in the current study was similar to the findings of Borghese (2005) who used the same Egyptian breed. The average daily milk yield ranged between 8·35–13·87 kg/buffalo/d in both pure Egyptian and Italian buffalo (Varricchio et al. 2007; Araújo et al. 2012; Morsy et al. 2014). The results of this study in the three genetic types were within this range, although the BC revealed higher daily yield when compared with EB and F_1 (7·74 and 3·92%, respectively).

The peak milk yield is the highest daily milk production at any time in lactation. F1 and BC had a higher peak yield than EB (6·36 and 7·67%, respectively). However, all of them were in the range 8·14–11·30 kg reported by others (Hamid et al. 2003; Kianzad et al. 2013). The higher peak milk yield might be attributed to greatly productive animals and more efficient use of feed (Hamid et al. 2003). Bhutkar et al. (2014) stated that days to attain peak yield is a crucial factor which influences lactation yield, lactation length and shape of the lactation curve. A growing number of studies have found that the days to attain peak milk yield were in the second and towards the start of the third month (Sarubbi et al. 2013). The results of this study were within this range. However, there was no significant difference between the different genetic types in this study, but BC had the highest milk yield and peak with longer days to attain the peak, which was compatible with the findings of Kianzad et al. (2013). They found a positive correlation between peak milk yield and days to attain peak yield.

Fat % of EB in the present study was in agreement with the reported range (5·95–7·0%) by others on Egyptian buffalo (Macedo et al. 2001), but was lower than the findings (7·99%) of other (Morsy et al. 2014). Fat% in F_1 and BC was lower than that of pure Italian buffalo 7·9–8·69% (Rosati & Van Vleck, 2002). The slightly higher fat % in EB might be due to the fact that the daily milk yield had a negative significant correlations with fat % (Barros et al. 2014), demonstrating that direct selection for improving milk production would result in decreased the concentrations of fat (Bampidis et al. 2012). Thus, higher milk yield has a consequential dilution effect on fat concentrations (Quist et al. 2008). The three genetic types in this study had the same protein % and TS % which were compatible with the findings of other in Egyptian buffalo (Morsy et al. 2014), Mediterranean buffalo (Macedo et al. 2001; Varricchio et al. 2007; Bampidis et al. 2012) and Murrah buffalo (Araújo et al. 2012; Barros et al. 2014), while it was lower than the range reported in pure Italian buffalo (Rosati & Van Vleck, 2002).

Effect of THI levels on milk yield and composition of different genetic types

There have been conflicting results on the effect of calving season on milk yield. While some authors have found no difference (Fooda et al. 2011; Araújo et al. 2012), others have reported that milk yield decreased under hot environmental conditions (Marai et al. 2009). However, our results were in accordance with the majority of studies that have found that THI had a negative impact on milk yield. Improved feeding and management may be conquering the conflicting results which caused by stress factors. Livestock performance might be influenced by THI (over

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the thermoneutral zone of dairy cows) in several ways: Firstly, fodder deficiency (intake, quality and utilisation), disturbances in metabolism, enzymatic reactions and hormonal secretions (Young, 2002). Secondly, animal struggling in losing heat will decrease its heat production by depression of the feed intake (Mader & Davis, 2004). Thirdly, heat stressed cows rely on glucose for body energy requirements, thus a lesser amount of glucose is directed to the mammary gland and consequently lowered the milk production (Aggarwal & Upadhyay, 2013). Fourthly, heat stress causes vasodilatation with amplified blood flow to skin surface, high rectal temperature and decreased metabolic rate, which associated with negative impacts on production and reproduction in dairy animals (West et al. 1999).

EB and BC revealed some evidence of robustness at the different THI levels under subtropical conditions. Their daily milk yield did not change under different levels of THI, while in F_1 it decreased by 18·88% from low to high THI. This result was compatible with the results of Pawar et al. (2013). They concluded that heat stress lowered daily milk yield by 18·2%. This may be due to the fact that BC had a higher Egyptian blood percentage, therefore adapted well under hot Egyptian environments. There have been conflicting results on the effect of THI on milk composition. While some authors have found no differences (Araújo et al. 2012), others have reported that milk fat and TS% decreased under hot environmental condition (Bernabucci et al. 2015). However, in the current study the THI had a negative impact on fat and TS% which were comparable to the study performed by Coroian et al. (2013). This may be due to milk yield that was negatively correlated with fat and TS (Khosroshahi et al. 2011). Moreover, heat stress had a negative effect on the secretary function of the udder (Silanikove, 1992). Most of the milk compositions (protein, SNF, lactose and ash) were not different under different levels of THI and this was in accordance with other studies (Khosroshahi et al. 2011; Bampidis et al. 2012). This may be an indication for the satisfactory management conditions in the farm all over the year (Marai & Habeeb, 2010; Araújo et al. 2012; Bampidis et al. 2012).

Consumption of buffalo milk in Egypt has been increasing and the improvement of dairy buffalo is necessary for an efficient production. Consequently, EB crossed with Italian buffaloes, such as BC, tend to be the best in milk yield, average daily milk and peak yield with evidence of robustness under sever hot condition which are approximately similar to that of EB. Therefore, it is recommended to encourage producers to increase the number of BC animals in their farm for improving the milk production to fulfil the demand of Egyptian markets.

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