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Simulated breeding scenarios for improving Hejaz goat performance in subtropics

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Abstract
This simulation study aimed to predict potential breeding program of increasing milk and meat production of Hejaz goat in subtropical areas. Computer ZPLAN$^+$ software was used to simulated breeding program of five-year duration. ZPLAN$^+$ was provided by a wide range of performance, phenotypic and genetic parameters of studied selection criteria and breeding objectives; milk and meat production. Furthermore, a close breeding scheme was assumed of ten selection groups where nucleus buck's genetic material was disseminated into multiplier and commercial unites. The result of simulated scenario was increasing milk and meat productivity by 0.199 and 0.107 kg, respectively, under assumed subtropical conditions where Hejaz goats habitat. Therefore, such breeding program was found sustainable in short term in which genetic gain showed reasonable increment regardless the trait's genetic makeup or heritability values. On the other hand, it has been found that genetic gain was sensitive to changes in heritability values. The change of heritability values varied from 0.10 to 0.40 for total milk and meat production. The changes in the magnitudes of the genetic gain stress the importance of using more reliable estimates of these traits in the breeding program. Further work on application of long-term breeding program is needed and updated estimates of genetic and economic values for Hejaz goat breed is also needed.

Key words: Hejaz goat, subtropics, breeding scenarios, genetic gain, ZPLAN$^+$ software, heritability.

Introduction
The subtropical aridity of Arabian deserts and subtropics influence livestock production in each country of these regions. As a consequence, climate of these regions is also influenced and characterized by long, hot and dry summer and short and cool winter [1]. The prolonged effect of environmental stresses of such heat and drought challenges indigenous livestock to tolerate heat, diseases and adapt for poor conditions. It is commonly accepted that the indigenous livestock breeds of these region have better adaptation to local subtropical conditions [2]. A good example is Hejaz goat that is historically assigned to Hejaz region in Kingdom of Saudi Arabia (KSA) [3]. Hejaz goat is dominant goat in areas and surroundings from the South nearby Nejd up to the North nearby Red Sea [3]. In present time, Hejaz goat is close to Aardi goat in KSA [4,5], Black Bedouin and/or Dihawi in Jordan [6-8], Black Bedouin in Palestine [9] and Jabli goat in Syria [10]. Long time ago, Hejaz goat were bred by nomads of the Arabian Desert [3]. It is since then the goat of Bedouin as it might therefore be known as Bedouin goat, Black Bedouin goat or desert goat. In fact, the Hejaz goat is often referred to as a dwarf goat and has ancestry with African dwarf goat [3,11]. Overall, Hejaz goat is found in areas of first domesticated goat (*Capra hircus*) in the Fertile Crescent of the Near East some 10,000–11,000 years ago [11-14]. Considering recent molecular evidences, Hejaz goats were found to be related to African and Eurasian goat breeds [12]. It has been noticed increasing interests of Hijaz goat under recent climate change conditions for their better tolerance of heat stress and diseases as well as durability and low water consumption with reasonable performance during extensive grazing [5,10,15].

The Hejaz goat breed is reared in Southern parts of Jordan, mainly in Wadi Rum valley that is geographically connected to Northern-Western parts of KSA. The goat breeds are preferred by Bedouins primarily because of their ability to tolerate tropical conditions of the region where heat stress is day time dominant and cold stress is night time dominant. In addition, they are well adapted to water and feed scarcity making them the best animal for the extensive production system [8]. However, the production capacity of this breed is low when compared to other indigenous and exotic goat breeds in the region [16]. On the other hand, Hejaz goat was characterised as meat type breed reared under the harsh desert conditions [16,17]. In general, goat individuals are selected primarily for milk yield as well as morphological traits in developing countries [18]. In Jordan for example, farmers were breeding Hejaz goat, for both milk and meat production to make a dual purpose type of goat [18]. Therefore, optimized breeding programs design to improve milk and meat production traits of this breed is requested. Feasible genetic gain was reported for optimized breeding program aimed for increasing meat yield of Hejaz goat only using simulation models [17]. However, Hejaz goat is requested to be bred for both milk and meat yield as most farmers stated [16]. This might be achieved by simulating breeding program Hejaz goat as dual purpose breed for subtropical area using simulation software such as ZPLAN$^+$ [19]. This study aimed to simulate genetic potential of increasing milk and meat production of Hejaz goat using ZPLAN$^+$ software under subtropical conditions.

Materials and Methods

Population structure and selection groups: The breeding structure simulated as a close breeding scheme consisted of three tiers; nucleus, multiplier and commercial. The nucleus was the tier that generates genetic gain of bucks to be sires of next bucks or sires for multiplier. This tier was closed with all replacements sourced from within and selected on indices that included all available information. The multiplier unit expanded the genetic material of selected does and bucks for use by the commercial unit. The total population of 75,000 breeding does was considered, with 1000 does (0.013%) forming the nucleus, 24,000 does (0.32%) forming the multiplier unit and the remaining 50,000 (0.667%) does from population of the commercial unit. Bucks to be used as sires in the multiplier unit were selected from a subset of bucks that did not qualify to be used in the nucleus. Furthermore, the selection criteria and selection were assumed to be measured in the nucleus and the multiplier units by breeder in both nucleus and multiplier units, whereas it was assumed to be done by farmers in the commercial units. All the selection groups had information contributed from records on the each individual. The modeled population structure resulted in ten selection groups (SG) as in following. First and third SGs were bucks from the nucleus to breed bucks and does for the nucleus, respectively. Second and fourth SGs were does from the nucleus to breed bucks and does for the nucleus, respectively. Fifth and seventh SGs were bucks from the nucleus to breed does for the multiplier unit and bucks for the commercial unit, respectively. Sixth and eighth SGs were does from the multiplier unit to breed does for the multiplier unit and bucks for the commercial unit, respectively. Finally, ninth SG was bucks from the commercial unit to breed does and slaughter stock for the commercial unit; and tenth SG was does from the commercial unit to breed does for the commercial unit and slaughter stock.

Table 1. Description of breeding objectives and their selection criteria.

Breeding objectives	Economic value	Description
Total meat yield	1.65	Amount of meat produced from 180 days kid(s) per doe
Total milk yield	1.2	Amount of milk produced per doe
Selection criteria		
Birth weight (Bwt) (kg)		Kids birth weight
Weaning weight (WWt) (kg)		Weaning weight of kids
Daily gain weight (DGWt) (kg)		Daily gain of kids
Total milk production (TMP) (kg)		Milk produced per lactation
Partial milk production (PMP) (kg)		Partial milk produced in a lactation
Prolificacy (PRFC) (kg)		Number of kids per kidding
Dam weight (DWt) (kg)		Does weight at kidding
Market body weight at (MBwt) (kg)		Body weight of kids at marketing time (180 days)

ZPLAN⁺ modelling software: The computer ZPLAN⁺ software was recently developed using modern programming technologies and a web-based GUI [20, 21]. ZPLAN⁺ software was provided for this study by Dr. Helge Täubert; vit - Vereinigte Informationssysteme Tierhaltung w.V., Germany. www.vit.de. The breeding programs and their parameters were pre-defined and then the software calculated annual genetic gain for the breeding objectives. The scheme was applied to real size of Hejaz goat populations in Jordan with total of 75,000 heads [22]. These simulated scenario scheme the population parameters and selection strategies were unchanged and mating of non-related individuals in order to avoid inbreeding during the simulated period of five years. The scenario was considered only one round of selection with defined selecting individuals and groups and optional choices of pedigree matrix and gene flow. It is good to mention that economic optimization for simulated scenario was not performed.

Breeding objective and selection criteria: The breeding objectives considered in this simulating breeding scheme were milk and meat production (Table 1). Consequently, selection criteria traits considered in the breeding objective are indicated in Table 1. They were total milk yield of doe (TMY), partial milk yield (PMY), doe weight at kidding (DWt), total meat yield of doe (TMY), birth weight of kids (BWt), weaning weight of kids (WWt) and daily gain of kids (DGK) and market weight of kids at age of six months (MWt). The inclusion of each trait into breeding objectives was because of its direct or indirect relationship. For example, TMY was estimated as amount of meat at marketing time per doe (total body weight of marketed kids per doe mated). On the other hand, calculated economic values of the breeding objectives based on inputs, such as feed, husbandry and marketing costs, as well as for outputs, such as income from sale of milk and meat output. The economic data were collected from the country Consumer Price Index statistical [23] and the research stations records. Table 1 shows traits considered in estimating economic value of the breeding objective based on a reintegrated bioeconomic model developed by Rewe *et al.* [24].

Physiological, genetic and phenotypic parameters: Phenotypic parameters, pedigree and performance records of the breed were taken and estimated from records of goat farm in Agriculture Station at Mutah University in Jordan. The used data of those records in this study are presented in Table 2. On the other hand, the genetic parameters used in the simulated program were based on parameters of the Black Bedouin goat [17] and from literature for tropical and dwarf goat breeds; goats of tropics [25], Black Bengal goats [26], blended goats [27], dwarf goats [28], Draa goats [29], Emirati goats [30], West African goats [31]; Arsi-Bale goats [32] and Markhoz goats [33]. These parameters are presented in Tables 3 and 4. In some cases where required parameters were not available from those tropical and dwarf goat breeds published data, parameters of breeds such Damascus and Mountain goat that are already available in Jordan were used instead [6, 16]. The parameters were phenotypic standard deviation, heritability and repeatability (Table 3) and genetic and phenotypic correlations (Table 4) of each trait. The litter effect was assumed into simulated scenario with effect from 10 to 20% in the model.

Results and Discussion

Genetic gain for the breeding objectives: The simulated trend in genetic gain for studied traits of the five-year breeding program is illustrated in Fig. 1. As it is expected, the genetic gain per year for milk and meat production linearly increased. The average increment for milk production (0.199 kg) was higher than that for meat yield (0.107 kg) in five years duration of the simulated goat breeding program (Fig. 1). For both objectives, it seems that milk yield per doe as selection criterion was the main contributors to the genetic gain of milk production, whereas body weight at market time was

Table 2. Input parameters for modelling the breeding programs of Hejaz goat and traits cost used in estimation breeding values of breeding objectives.

Biological parameters	Value	Economic parameters	Cost (Euro)
Productive lifetime bucks in breeding unit years	3	Price of feed	0.20
Productive lifetime for does in breeding unit, years	3.5	Doe recording milk total	0.20
Productive lifetime for sires in commercial unit, years	3	Doe recording milk partial	0.20
Productive lifetime for does in commercial unit, years	4	Recording birth weight	0.15
Buck survival rate in both, %	85	Recording weaning weight	0.20
Doe survival rate in both, %	85	Recording dam weight	0.25
Age at first calving for sires in breeding unit, years	2.5	Recording prolificacy	0.50
Age at first calving for dams in breeding unit, years	2.0	Recording daily gain	0.50
Age at first calving for sires in commercial unit, years	2.5	Fixed costs	3.90
Age at first calving for dams in commercial unit, years	2.0	Labour cost per animal	2.00
		Veterinary services cost/animal	0.20
		Reproduction costs per doe	0.50
		Marketing costs total per year	100.00
		Price of meat per kg	10.00
Investment parameters			
Parameter	Value	Parameter	Value
Kidding interval, days	365	Age at first kidding in days	730
Kidding rate, number of kids	1.1	Constant of maintenance energy requirement	0.35
Pre-weaning survival rate, %	0.93	Constant of energy for production	0.35
Post weaning survival rate, %	0.90	Birth weight, kg	3.50
Doe survival rate, %	0.90	Weaning weight, kg	16.00
Doe weight, %	60	Daily gain, g	0.15
Milk yield, kg	170	Sale weight for males, kg	40.00
Dressing percentage	0.48	Sale weight for females, kg	35.00
Consumed meat percentage	0.70	Energy content kcal in feed mix/kg	2500
Replacement rate per doe per year, %	0.20	Energy content kcal in pasture/kg	2000
Weaning age in days	90	Energy content kcal in concentrates/kg	3100
Sale age in days	180	Amount of milk fat in total milk/g	5000
Economic value =1.65			

Table 3. Phenotypic standard deviation (σP), heritability and repeatability of selection criteria (lower case letters) and breeding objective (upper case letters) applied to the simulation scenario.

Name	(σP)	Heritability	Repeatability
Birth wt	0.60	0.38	0.70
Daily gain	0.16	0.36	0.63
Dam wt	4.50	0.41	0.68
Market wt	4.00	0.16	0.53
Partial milk	0.05	0.37	0.65
Weaning wt	0.50	0.23	0.41
Milk yield	6.50	0.21	0.41
Prolificacy	0.06	0.12	0.25

the main contributor to meat production. These results showed that measuring those traits on both bucks and does was genetically worthwhile. In particular, the accuracy of selection was assumed for buck selection groups in nucleus unit. Therefore, the great genetic improvement would be expected as long as high proportion of bucks used. Similarly, great improvement was noted when high proportion of beef bulls used of high selection accuracy in nucleus scheme [34, 35]. However, in term of accuracy, the studied criteria were measured with highly accuracy from the Station's records. These were performed for more accurate outcomes and to be in a compliance with previous reports that indicated accurate criterion had high impact on selected bucks and does. However, some difficulties were observed for measuring high-cost criteria such as milk yield in some multiplier farms on candidates that likely to have a high impact on the breeding population. In most livestock breeding programs, the sires used in nucleus have the greatest influence on the entire population genetic gain. It is the situation in general of breeding goats for meat production [36]. In particular, the selected sires in nucleolus population had genetically influenced the other populations as their genes solely flow into the other two populations. As a consequence, the selected bucks have the greatest influence on entire population. These results achieved under assumptions in which generation interval of 3.56 years and for five-year breeding program with the pre-assumed genetic parameter estimates. The later was assumed on hypothesis that this study evaluated genetic gain utilizing the pre-published and estimated parameters on same breed or breeds of morphological or geographical closeness. Similarly, it was reported that annual genetic gains were positive for meat production traits of Boran cattle under tropical conditions of Kenya [35].

Potential genetic gain to changes in heritabilities: The results, in general, showed changes in the level of heritability estimates changed the level of genetic gain in both breeding goals (Fig. 2). In simulation studies, genetic parameter estimates may come from another population, a different generation and from a limited number of animals and may therefore be inaccurate and result in less efficient indices. In order to avoid such situation genetic parameters used in constructing a selection index and thus estimating genetic gain was assumed ahead based on same breed and most phenotypically as well as geographically related. This procedure was performed by many researchers [36, 37]. In order to overcome such a problem, another simulated scenario were performed assuming changes in the heritabilities values of studied criteria under investigation, keeping the genetic variance, repeatabilities and the genetic and phenotypic correlations constant. The change of heritabilities values were varied from 0.10 to 0.40 only for total milk and meat production (Fig. 2). The assumption was that reliable genetic parameter estimation would allow for development of optimal selection indices that are directly

Table 4. Phenotypic (above the diagonal) and genotypic (lower the diagonal) correlations among selection criteria applied to the simulations scenarios.

Traits	Birth wt	Daily gain	Dam wt	Market wt	Partial milk	Weaning wt	Milk yield	Prolificacy
Birth wt		0.25	0.26	0.20	0.30	0.55	0.13	0.30
Daily gain	0.30		0.40	0.42	0.40	0.09	0.40	0.25
Dam wt	0.05	0.00		0.54	0.30	0.25	0.30	0.25
Market wt	0.15	0.35	0.54		0.10	0.35	0.01	0.55
Partial milk	0.10	0.00	0.15	0.10		0.00	0.52	0.30
Weaning wt	0.45	0.40	0.20	0.37	0.13		0.00	0.25
Milk yield	0.20	0.15	0.45	0.20	0.89	0.10		0.35
Prolificacy	0.30	0.25	0.00	0.25	0.25	0.42	0.26	

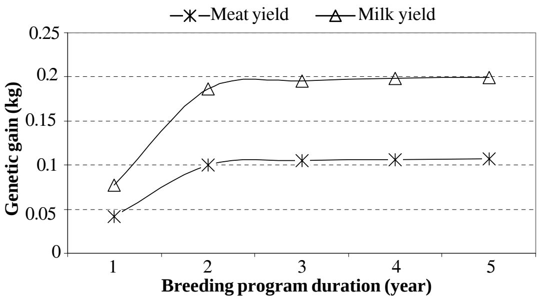

Figure 1. Genetic gain of each year in breeding program for improving milk and meat yield in Hejaz goat.

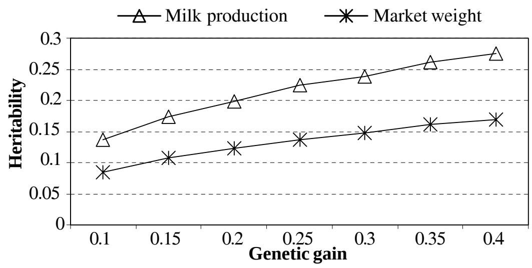

Figure 2. Genetic gain change as response to heritability estimate change in breeding program for improving milk and meat yield in Hejaz goat.

applicable to programs selecting for improved performance. Knowledge of the effect of changes in the genetic parameters is required for effective breeding program design [38]. The simulated scenario showed that the genetic gains were changed for each breeding objective due to changes in heritability values (Fig. 2). The genetic gain in major two traits was changed when the heritability estimates were changed. It is clear that the values of genetic gain were indeed increased for milk yield and meat yield as a result of increasing heritability values from the values of the simulation model; 0.21 and 0.16 for milk and meat production, respectively. In details, the gain in meat slightly increased in comparison with the increment of milk yield (Fig. 2). Therefore, the genetic gain in milk linearly increased when heritability values increased from 0.1 to 0.4 at an average gain of 0.267 kg. It is amazing that deviation of genetic gain for both breeding objectives at end point, when heritability was 0.4 (0.130 and 0.085), was same amount as the genetic gain at start point when heritability was 0.1 (0.137 and 0.085). These results indicated that within a range of 30% increment in heritability the amount of expected genetic gain were doubled. In agreement, changes in heritability values were sensitive to more changes in the genetic gain and profitability of the breeding program [36]. They also stressed on importance of using reliable genetic estimates of traits in any breeding program in order to scale the genetic gain and profit per animal.

Furthermore, heritability value of more than 0.4 was not assumed considering that major heritability values are not more than that limit for studied criteria in most goat breeds. Reasonable changes occurred in the expected genetic gain and as a consequence improvement might be achieved in the breeding program. This indicates that heritability values of milk yield and its indirect measures are more important than heritability values of meat yield and its direct measures in the design of breeding programs of Hejaz goat. Finally, the changes in the magnitude of the genetic gain per doe emphases the importance of using reliable estimates of these traits in any breeding program. The estimates for the traits used in this study were mostly estimated under subtropical conditions and were assumed to be similar to those of Heijaz goat.

Conclusions

The present study showed good potential for improvement of Hejaz goat being dual breed of milk and meat production. A successful breeding program is possible to be applied for improving productivity in subtropical conditions that mimic real condition of rearing Hejaz goat. Therefore, such breeding program of close scheme is sustainable program in short term in which genetic gain showed reasonable increment regardless the trait genetic makeup or heritability values. The changes in the magnitudes of the genetic gain stress the importance of using reliable estimates of these traits in the breeding program. Further work on application of long-term breeding program is needed, and estimation of required genetic and economic values for Hejaz goat breed is also needed.

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