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Evaluation of Egyptian sheep production systems: I. Breed crosses and management systems

H. Almahdy*, M. W. Tess†¹, E. El-Tawil‡, E. Shehata*, and H. Mansour‡

*Sheep and Goat Research Department, Animal Production Research Institute, Ministry of Agriculture, Cairo, Egypt; †Animal and Range Sciences Department, Montana State University, Bozeman 59717-2900; and ‡Animal Production Department, Ain-Shams University, Cairo, Egypt

ABSTRACT: Our objective was to evaluate life-cycle performance of flocks of two Egyptian breeds, Rahmani (R) and Ossimi (O), and their crosses with Finnish Landrace (F) in two management systems. Management systems were one mating season per year (1M) and three mating seasons per 2 yr (3M). Breeds and crosses studied included purebred R and O, F₁ crosses ½F-½R (FR) and ½F-½O (FO), and *inter se* matings of ¼ F-¾ R (RFR) and ¼ F-¾ O (OFO). A dynamic computer model was used to simulate animal performance and enterprise efficiency and profit. Two measures of life-cycle feed conversion (biological efficiency) were computed: kilograms of TDN input per kilograms of empty body weight output (TDN/EBW) and kilograms of TDN input per kilogram of carcass lean output (TDN/CLN).

Profit was measured as gross margin (income minus variable costs per ewe per year, GM/EWE). Input parameters for the model were obtained from published results and analyses of data collected from experimental flocks of the same genetic stocks in Egypt. Profit for FR and RFR was 42 and 6% higher in 1M than in 3M. However, profit for all other genetic types was 4 to 8% greater in 3M than in 1M. Breed rankings changed depending on the measure of evaluation (i.e., biological efficiency or profit). Maximization of system output did not necessarily improve efficiency. Under accelerated lambing systems, greater overhead costs associated with labor and feed offset gains in ewe productivity. Genetic stocks should be matched to resources and management systems.

Key Words: Sheep, Breeds, Crossbreeding, Efficiency, Profitability, Systems Analysis

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Introduction

Egyptian sheep breeds are characterized by extended breeding seasons, high fertility, and low prolificacy. Currently in Egypt efforts are being made to intensify production systems, primarily through changing reproductive management and crossing native breeds with introduced breeds.

Two management systems have been studied, one mating season per year and three mating seasons per 2 yr (Aboul-Naga and Aboul-Ela, 1987). Most crossbreeding schemes studied have been based on crosses between native (Ossimi [O] and Rahmani [R]) and imported breeds (e.g., Merino, Suffolk, Romanov, and Finnish Landrace [F]). One of the most significant trials with respect to number of animals, duration, and available information involved crossing O and R with F producing ½ F ½ O (FO) and ½ F ½ R (FR) (Aboul-Naga, 1988). The

breeding plan was to produce ¼ F ¾ O and ¼ F ¾ R, which were *inter se*-mated to produce (OFO) and (RFR) as target breeds. Evaluation of these breeds has been limited to comparisons based on single-trait measures of biological performance.

The objective for this study was to evaluate life-cycle performance and profitability of flocks of two Egyptian breeds along with their crosses with Finn sheep in two management systems using systems analysis techniques.

Materials and Methods

Simulation Model. A dynamic computer model was used to simulate animal and enterprise performance. The model was a modified version of the deterministic lamb and wool production model used by Wang and Dickerson (1991a,b,c), which they adapted from the Texas A&M University Sheep Model (Blackburn and Cartwright, 1987a,b,c). It was modified to accomplish the simulation of different breed groups under Egyptian production and management systems.

In this study, two native Egyptian fat-tailed breeds of sheep, R and O, and their crosses with F were considered.

¹To whom correspondence should be addressed (phone: 406-994-5610; fax: 406-994-5589; E-mail: mwteess@montana.edu).

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Table 1. Input parameters used for different breed groups^a

Breed	α	β	κ	CR	LR	MR	FT	LN	MK	WL
R	47.27	.956	.0042	72	131	14	27.0	65.6	6.95	1.45
FR	47.62	.972	.0043	78	173	30	18.0	69.9	7.92	1.77
RFR	49.96	.978	.0042	73	154	22	18.0	67.0	7.00	1.45
O	42.84	.971	.0050	68	122	14	22.5	65.6	4.78	1.37
FO	46.08	.973	.0046	72	164	16	14.5	67.9	7.08	1.79
OFO	48.76	.975	.0043	69	150	20	16.0	66.1	5.50	1.60

^aR = Rahmani, O = Ossimi, F = Finn; α = asymptotic mature weight; β = parameter related to early change in body weight; κ = parameter defining maturity rate; CR = conception rate; LR = lambing rate; MR = mortality rate; FT = fat percentage; LN = lean percentage; MK = milk production; WL = wool production. Growth curve parameters from Elshennawy (1993); CR, LR, and MR from Mansour and Aboul-Naga (1988); FT and LN from Fahmy (1986); MK and WL from Shehata (personal communication).

Crosses were FR, FO, RFR, and OFO, corresponding to Aboul-Naga (1988). All simulated crosses were bred *inter se* and managed as purebreds. Input parameters used to describe the breeds are presented in Table 1. Individual and maternal heterosis estimates (Table 2) were obtained from Elshennawy (1993) and Mansour and Aboul-Naga (1988), and the amount of heterosis expressed was calculated as a linear function of expected heterozygosity.

Simulated management was identical across breed groups and patterned after management systems used by sheep producers in Egypt. From December through May flocks grazed Egyptian clover pasture, supplemented with .20 kg of concentrates·ewe⁻¹·d⁻¹. Average diet composition during this period was 21% CP and 65% TDN (DM basis). From June through November, flocks grazed crop stubble, green fodder (sorghum), clover hay, and rice straw in roughly equal proportions, again supplemented with .20 kg of concentrates·ewe⁻¹·d⁻¹. Average diet composition during the summer and autumn was 11% CP and 57% TDN. Additional supplement was provided to ewes at a rate of .25 kg·ewe⁻¹·d⁻¹ for 2 wk prior to the mating season and from the last 4 wk of pregnancy through the 1st wk of lactation. The supplement contained 24% corn, 38% cottonseed meal, 37% wheat bran, and 1% salt (26% CP, 77% TDN).

Animals were sheared in March and September. Ewes and rams were first mated at 18 mo of age. Ewes were culled if they exceeded 9 yr of age, failed to conceive for two consecutive seasons, or experienced health or soundness problems.

Two management systems were simulated: yearly lambing (**1M**) and an accelerated system of three lambings every 2 yr (**3M**). In 1M, breeding started May 15 and lasted until August 15 (lambing October to January). Lambs were weaned at 4 mo of age. In 3M, mating seasons started May 15, January 15, and September 15 and lasted for 35 d. Lambs were weaned at 2 mo of age. In both systems, market lambs were sold at 6 mo of age. Facilities required for both management systems were assumed to be the same but would be used more frequently in the 3M system. Labor and feed were proportional to numbers of animals, which would differ between systems.

Performance traits in the model were simulated deterministically as described by Blackburn and Cartwright (1987a,b,c) and Wang and Dickerson (1991a,b,c), except for reproduction and mortality, which were stochastically simulated (described below).

Asymptotic mature weight (α) and its relationships with body weight for purebreds and crossbreds were taken from Elshennawy (1993). Mature weight for males was simulated as 1.25 α for females. Birth weight for single-born lambs was simulated as 7% α (Mousa, 1989; Elshennawy, 1993) then adjusted for number of fetuses, mature weight of ewe, and current weight of the ewe (Blackburn and Cartwright, 1987a,b,c).

Growth potential was simulated from a theoretical sigmoid curve, which combines linear preinflection growth with a postinflection growth curve derived by Brody (1945), using the following equations:

$$WT = BW + t (WTI - BW)/Ti \text{ when } t < Ti$$

Table 2. Maximum individual and maternal heterosis for reproduction and growth^a

Trait	Finn-Rahmani		Finn-Ossimi	
	Individual	Maternal	Individual	Maternal
Conception rate	.40	-.27	-.76	.83
Lambing rate	.32	-.51	-.77	.66
Growth curve parameters				
α	7.89	-3.09	5.29	-2.25
β	-.06166	.00715	-.00662	-.05544
κ	-.00059	.00078	-.00103	.00102

^aFrom Elshennawy (1993) and Mansour and Aboul-Naga (1988). Heterozygosity assumed for FR, FO, RFR, and OFO = 50, 50, 37.5, and 37.5%, respectively.

$$WT = \alpha (1 - \beta e^{-\kappa t}) \text{ when } t > Ti$$

where **WT** is weight in kg at time *t* in days, **BW** is birth weight, **WTI** is weight at the age of inflection point **Ti**, β is a parameter related to early changes in body weight, and κ is a parameter defining maturing rate. Mousa (1989) calculated α , β , and κ for the R and O breeds, and Elshennawy (1993) calculated these parameters for both breeds and their crosses with F. Both studies reported an R^2 of .99 when the Brody function was applied. Time taken to reach inflection point (**Ti**) was calculated after the equation described by Taylor (1968). Fat and lean percentages at maturity were reported by Fahmy (1986).

Reproduction was based on a 148-d gestation period and a 17-d estrous cycle. Individual ewes were simulated in 1-d stages for 10-yr life-cycle production. Sheep were accumulated into classes, based on single or multiple birth, which in turn defined the structure of the simulated flock. To facilitate modeling of small flocks (not reported here), reproductive traits were simulated stochastically. Probability of conception of the ewe (**CR**) was determined from the genetic potential for each breed group then adjusted for the environmental effects of ewe body condition, weight change in the previous period, degree of maturity, and ewe age as described by Blackburn and Cartwright (1987a). Age correction for R and O and their crosses with F was accomplished using the following equation ($R^2 = .80$):

$$CR_{corrected} = -.1157 + .0585AG - .0077AG^2 + .0003AG^3$$

where **AG** is age (yr) of ewe. This equation was obtained from the analysis of reproductive data for the different breed groups collected at two experiment stations in Egypt. To simulate conception, the corrected CR was compared with a uniform random deviate.

Similar to CR, probability of lambing (**LR**) was input as a genetic mean. To simulate phenotypes, LR was adjusted for the environmental effects of current weight, weight change for the current period, and maturity as described by Blackburn and Cartwright (1987a). Then, LR was corrected for age of ewe according to equations calculated for R and its crosses ($R^2 = .94$) as follows:

$$LR_{corrected} = -.3219 + .1131AG - 0.0076AG^2$$

and for O and its crosses ($R^2 = .92$) as follows:

$$LR_{corrected} = -.2998 + .0978AG - .0060AG^2$$

The corrected LR were compared with a uniform random deviate to determine whether the ewe in question bore single or multiple lambs. Corresponding to the Egyptian data, multiple births were assumed to be 90% twins and 10% triplets or greater.

Average probability of abortion (.03) and ewe mortality rate (.03) were estimated from data collected at the Ministry of Agriculture, Egypt. Probability of mortality at weaning (**MRTW**) was corrected for weight, litter

Table 3. Output prices in Egyptian pounds (LE) used for different breed groups^a

Breed	Wool, kg	Weaned lambs, kg	Replacement ewes, kg	Manure, m ³
R	2.2	10.50	6.00	2.5
FR	2.1	10.00	8.30	2.5
RFR	1.9	10.25	6.00	2.5
O	2.1	10.50	5.85	2.5
FO	1.9	10.00	8.00	2.5
OFO	1.9	10.25	5.80	2.5

^aR = Rahmani, O = Ossimi, F = Finn. U.S. \$ = LE × 3.39.

size, and nutritional status (Blackburn and Cartwright, 1987a). Probability of mortality at birth was simulated as a linear function of MRTW as described by Wang and Dickerson, 1991a. Input genetic parameters for CR, LR, and MRTW for each breed group (Table 1) were calculated using estimates of additive and heterotic components reported by Mansour and Aboul-Naga (1988).

Equations used to simulate nutritional requirements for milk, wool, fetus, and animal growth were adapted from Blackburn and Cartwright (1987a); however, feed energy units were converted from ME to TDN. Manure output was calculated as 45% average DM consumption (Gutierrez et al., 1982).

Three quantitative definitions of system merit were computed, each reflecting a different production goal. Two measures of life-cycle feed conversion (biological efficiency) and one measure of profit were used for the evaluation of different systems. Life-cycle feed conversion was calculated as kilograms of TDN input per kilogram of empty body weight sold (**TDN/EBW**) and kilograms of TDN per kilogram of carcass lean sold (**TDN/CLN**). To calculate TDN/EBW and TDN/CLN, outputs of wool, weight (or lean), and manure were adjusted to a market lamb equivalent based on the relative values of outputs from different ages and classes of sheep.

Profitability was defined as gross margin (income minus variable costs per ewe per year, **GM/EWE**). Income included weaned lambs, surplus replacement ewes, culled ewes, wool, and manure. Variable costs included annualized costs for buildings and equipment, feed, veterinary care and supplies, shearing, and labor.

Average input and output prices for 1996 were determined locally and from prices set for different breed groups (Table 3) by the Animal Production Research Institute, MOA, Egypt. Feed prices (Egyptian pounds [LE]/kg) were .5 for concentrate, .15 for straw, .3 for hay, .05 for pasture, and .1 for green fodder. Annual costs for veterinary care and shearing were LE 12/ewe and LE 1.5/ewe, respectively. Daily labor expenses were assumed to be LE .05 per animal. Capital investment in building and equipment in both management systems was LE 10/ewe amortized to an annual cost using an interest rate of 9%. One U.S. dollar (\$) was equivalent to 3.39 LE (October 1996).

Experimentation and Statistical Analysis. For each breed group, flocks of 1,000 ewes were simulated for 10 yr in each of two different management systems (1M and 3M). Each combination of breed group and management system was replicated 10 times.

Note that because the model included stochastic as well as deterministic elements, replications of simulations using identical inputs showed variation in results. Hence, analyses of variance were possible, including the computation of *P*-values associated with comparisons of means. We do not claim that this variation is of the same magnitude expected from real production systems; however, it serves as a means to evaluate small differences in simulated results. Simulated data for TDN/EBW, TDN/CLN, and GM/EWE were checked for normality using the Univariate procedure of SAS (1990) and judged to be distributed normally.

Two-way analyses of variance with interaction were conducted for R and its crossbred groups and for O and its crossbred groups. Statistical model components were breed group, management system, and their interaction. Comparisons among breed groups were accomplished using Duncan's Multiple Range test. We chose to use a threshold of *P* < .01 for declaring differences significant. All analyses were conducted using the General Linear Model procedure of SAS (1990).

Results and Discussion

Biological efficiency and profit for R and its crosses under the two management systems are presented in Table 4. In 3M, both TDN/EBW and TDN/CLN were lowest for RFR and highest for R, with FR intermediate. Compared to R, crossbred systems improved life-cycle feed conversion 5 to 16%. Profit was similar for FR and R, but GM/EWE was approximately 60% higher for RFR.

In 1M, crossbred systems improved both life-cycle feed conversion measures by 15 to 21%. The FR was lower than RFR for TDN/EBW, but the ranks reversed for TDN/CLN. Profit was similar for the crossbred systems and averaged 86% greater than R.

Values for TDN/EBW and TDN/CLN were significantly lower for all O crossbreds compared to straightbred O (Table 5) in both management systems. Compared to O, FO improved TDN/EBW and TDN/CLN by 22 and 17% in 3M and 23 and 15% in 1M. Correspond-

ing improvements for OFO were 10 and 12% in 3M and 9 and 11% in 1M. Compared to O, FO increased profit by over 130% in both 3M and 1M, whereas OFO profits were over 70% greater than those of O in both systems.

Compared to 1M, accelerated lambing (3M) reduced TDN/EBW and TDN/CLN for all breed groups except FR (*P* < .01). The greatest reduction in TDN/EBW was 7% in R, followed by 4% for O, FO, OFO, and RFR. Similarly, TDN/CLN was reduced 6% for FO, 4% for R and OFO, and 3% for O and RFR. For FR, TDN/EBW and TDN/CLN increased by 10 and 8%, respectively, in 3M compared to 1M.

Results for GM/EWE indicated that FR and RFR performed better under 1M (*P* < .01), and other breed groups performed only slightly better under 3M (*P* < .05). Profitability of FR and RFR was 42 and 6% higher in 1M than in 3M. However, profit was 5% greater for O and R local breeds, 4% for FO, and 8% for OFO in 3M compared to 1M.

Accelerated lambing systems can increase the number of lambs weaned per ewe per year (Aboul-Naga et al., 1989), but early weaning also results in lighter weaned lambs. Lamb survival greatly influences productivity (Dickerson, 1970). Aboul-Naga (1988) demonstrated a large decrease in lamb survival with increased litter size, emphasizing the need for intensive management practices when higher reproductive rates are achieved (e.g., in the FR breed group). Jenkins (1986) showed that potential advantages of accelerated lambing systems were dependent on a market for light lambs or an efficient method of rearing lambs until they were sold. Nugent and Jenkins (1991) showed that the advantages of multiple exposures per year could be offset by the lighter weights of the younger weaned lambs, and producers could possibly realize greater economic returns in an intensive annual lambing system than in accelerated systems. Fogarty et al. (1984) reported greater kilograms and number of lambs weaned per ewe per year for an annual than for an accelerated lambing system. Rawlings et al. (1987) indicated that culling rate tended to be higher under reproductively stressful conditions, which increases replacement costs (Nugent and Jenkins, 1991).

Our results indicate that breed profitability may differ with the various environments created by alternate management strategies. Also, breed ranking may differ depending on the definition of system merit. Maximiza-

Table 4. Performance of breed groups based on Rahmani (R) and Finnish Landrace (F) for TDN/kg empty body weight sold (TDN/EBW), TDN/kg carcass lean sold (TDN/CLN), and gross margin/ewe (GM/EWE) in two management systems

Breed	Three matings/2 yr			One mating/yr		
	TDN/EBW	TDN/CLN	GM/EWE	TDN/EBW	TDN/CLN	GM/EWE
R	14.2 ± .06 ^{a*}	24.1 ± .12 ^{a*}	65.9 ± .97 ^b	15.3 ± .07 ^{a*}	25.2 ± .12 ^{a*}	62.5 ± 1.14 ^b
FR	13.3 ± .04 ^{b*}	23.0 ± .08 ^{b*}	67.9 ± .89 ^{b*}	12.1 ± .06 ^{c*}	21.2 ± .10 ^{b*}	117.7 ± 1.74 ^{a*}
RFR	12.5 ± .04 ^{c*}	20.2 ± .04 ^{c*}	107.6 ± 1.10 ^{a*}	13.0 ± .06 ^{b*}	20.8 ± .09 ^{c*}	114.3 ± 1.61 ^{a*}

^{a,b,c}Means within a column with different superscripts differ (*P* < .01).

*Means for management systems differ (*P* < .01).

Table 5. Performance of breed groups based on Ossimi (O) and Finnish Landrace (F) for TDN/kg empty body weight sold (TDN/EBW), TDN/kg carcass lean sold (TDN/CLN), and gross margin/ewe (GM/EWE) in two management systems

Breed	Three matings/2 yr			One mating/yr		
	TDN/EBW	TDN/CLN	GM/EWE	TDN/EBW	TDN/CLN	GM/EWE
O	16.2 ± .06 ^{a*}	24.8 ± .13 ^{a*}	36.9 ± .64 ^c	17.2 ± .08 ^{a*}	25.6 ± .13 ^{a*}	35.0 ± .77 ^c
FO	12.6 ± .05 ^{c*}	20.6 ± .08 ^{c*}	85.3 ± 1.14 ^a	13.4 ± .06 ^{c*}	21.8 ± .11 ^{c*}	82.4 ± 1.12 ^a
OFO	14.6 ± .04 ^{b*}	21.9 ± .08 ^{b*}	64.5 ± .81 ^b	15.6 ± .05 ^{b*}	22.8 ± .09 ^{b*}	60.0 ± .91 ^b

^{a,b,c}Means within a column with different superscripts differ ($P < .01$).

*Means for management systems differ ($P < .01$).

tion of system output is not necessarily biologically or economically efficient. Accelerated lambing and other intensive management practices can increase productivity, but greater overhead costs associated with labor and feed required may not be offset by gains in ewe productivity.

These results suggest that FR and RFR are not different for profitability, and these breeds are best suited for management systems using more traditional lambing schedules (i.e., once per year). Differences in profitability between accelerated and traditional lambing were small for Ossimi crossbreds (FO and OFO).

The RFR and OFO may be more desirable than FR or FO under Egyptian conditions. The RFR was equal to or superior to FR in both management systems for the traits evaluated here, and OFO was generally inferior to FO. Compared to the 1/4-Finn composites, 1/2-Finn composites require more intensive management due to their greater prolificacy. Also, the 1/4-Finn composites have a fat tail of more reasonable size, which remains an important factor in consumer preference.

Implications

Incorporation of Finn sheep genes into native Egyptian breeds will improve both biological and economic efficiency under annual or accelerated lambing systems. Half Finn-half Rahmani sheep are expected to be most efficient under annual lambing systems, whereas composites of 1/4 Finn-3/4 Rahmani will be easier to maintain because they can be managed like a single breed. Crosses involving Finn and Ossimi are expected to excel in accelerated lambing systems; however, accelerated lambing may not be more efficient than annual lambing in Egypt.

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