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With 5 tables and 1 figure in the text.

Productivity of Commercially Farmed Ostriches (*Struthio camelus*) in the Kingdom of Saudi Arabia (KSA)

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ملخص البحث

أجريت هذه الدراسة لغرض التعرف على المقدرات الإنتاجية للنعام في مزرعتين (أ و ب) بالمنطقة الوسطى بالمملكة العربية السعودية. الأمهات التي تم فقسها وتربيتها في المزرعة (أ) بدأت في وضع البيض في عمر 19 شهر وبمعدل 12 بيضة في الموسم خلال العام الإنتاجي الأول لها بينما بلغ معدل إنتاجيات الأمهات الأصلية والتي تم إستيرادها من فرنسا 1.2 ، 7 و 23 بيضة للأنثى الواحدة في الموسم خلال الأعوام الثلاثة الأولى على التوالي. في المزرعة الأخرى (ب) والتي بها أمهات تم إنتاجها في المملكة العربية السعودية بلغ معدل إنتاجياتها 13.5 و 35.2 بيضة للأنثى الواحدة في الموسم خلال العامين الإنتاجيين الأولين على التوالي. بلغ متوسط نسبة البيض التالف في المزرعتين 9.6% من جملة البيض المنتج وكانت الأسباب الرئيسية لتلف البيض وبالتالي إبعاده عن التحضين هي صغر الحجم، وجود ثقوب أوشقوق بالقشرة و زيادة خشونة القشرة الخارجية للبيضة. بلغ متوسط معدل الخصوبة في المزرعة (أ) نحو 52.5% بينما بلغ في المزرعة (ب) نحو 68.6%. كان متوسط معدل الفقس في المزرعتين (أ) و (ب) نحو 75% و 67.3% على التوالي. بلغ معدل النفوق الجنيني في المزرعة (أ) نحو 25% بينما في المزرعة (ب) نحو 32.7%. كان أغلب النفوق الجنيني في المزرعة (أ) متأخراً (61.9%) بينما كانت البقية (38.1%) نفوقاً جنينياً مبكراً.

Summary

This study was conducted to record preliminary data on the productivity of ostriches (*Struthio camelus*) in two ratite farms (A and B) in central region of the Saudi Arabia. Breeders in Farm A started egg laying at the 19th month of age with an average production of 12 eggs per female in their first season. Older (imported) breeders had averages of 1.2, 7 and 23 eggs per female in the first three production seasons in Saudi Arabia. Farm B breeders had an average production of 13.5 and 35.2 eggs per female in their first two production seasons. The crude rate of egg defects in the two farms was 9.6%. The main causes of egg defects were egg undersize, presence of holes, cracks and rough shells. Mean fertility rates of ostrich eggs were 52.5% in Farm A and 68.6% in Farm B.

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The mean hatchability rates were 75% and 67.3% in Farm A and B, respectively. Farm A had an overall embryonic mortality of 25% of fertile eggs whereas Farm B had 32.7% overall embryonic mortality. Most of Farm A embryonic mortality (61.9%) was late while the remaining 38.1% of mortality occurred during early embryonic development.

Introduction

Ratites, particularly ostriches, have recently received an increasing attention as meat-producing birds (Cilliers, 1998; Verwoerd, 2000). Meat from ostriches is becoming increasingly popular throughout the world. Other important ostrich products include leather, oil and feather. Therefore, ostrich farming is emerging as a promising profitable investment (Perelman, 1998). Many countries, including Saudi Arabia, are witnessing significant growth in the number of investors allocating money and efforts towards the establishment of ratite enterprises. This paper presents information on the productivity of ostriches (*Struthio camelus*) raised commercially in two farms in Saudi Arabia.

Materials and Methods

The study was conducted in two ratite farms (A and B) at Al-Qassim region, central Saudi Arabia.

Farm A:

This Farm was established in 1997. The breeding stock, *Struthio camelus* var *domesticus*, was imported from France as ready-to-lay breeders and was composed of 400 birds with male to female ratio of 1:2 (i.e. 133 males and 267 females). The birds were housed in communal pens with dimensions of 100 X 200 *meters* each. Each pen was supplied with two shaded areas of 10 X 20 *meters*, eight water troughs and four concrete feeders. The stocking density ranged between 60 and 70 birds per pen. The farm had a hatchery section with incubating and hatching equipment (Mayenne Eclosion, St. Jean Sur Mayenne, France). The chick rearing section was composed of 24 rooms of varying areas ranging between 9 and 32 m^2 each. The grower birds (above 3-month-old) were housed in several pens of varying areas, ranging between 20 X 30 m and 100 X 200 m. All grower pens were supplied with shade, feeders and drinkers.

Farm B:

This farm was established in the year 1999. The parent stock, also *S. camelus* var *domesticus,* was purchased locally as young chicks from a pioneer ostrich project which had imported its parent stock from South Africa. The breeders in this Farm were housed as couples (a male to female ratio of 1:1) in pens with dimensions of 15 X 50 m. Each pen was supplied with shade, a feeder and a water trough. The farm also had incubating and hatching equipment (Natureform Inc., Jacksonville, Florida, USA). The chick-rearing section was composed of five rooms and outside exercise areas ranging from 90 to 120 m². The growers section was composed of 12 pens of varying areas, ranging from 320 to 6000 m², and was supplied with shaded areas, feeders and drinkers.

Farm A manufactured its own feed while the source of feed for Farm B was a commercial feed supplier (ARASCO, Saudi Arabia). Feed was provided *ad libitum*.

Production operation in the two farms:

Laid eggs were removed from pens either in the late afternoon or in the early morning. After labelling with date and pen number, eggs were transported to the hatchery section where they were inspected for incubation suitability. Defective eggs were discarded. Non-defective eggs were cleaned by tissue paper, fumigated by potassium permanganate and formaldehyde mixture (80 gm potassium permanganate in 130 ml 40% formaldehyde per cubic meter) for 20 minutes (Horbanezuk and Sales, 1998). Eggs were then stored in a special storage room in the hatchery section at 18ºC and 60% – 70% relative humidity for 2 – 6 days. During storage, eggs were positioned vertically with the air cell uppermost until transferred to the incubator. Twelve hours prior to this, eggs were fumigated again and preheated to 25ºC (Deeming and Ar, 1999). Eggs were then incubated at 36.2ºC and 25% relative humidity. Initial candling for fertility assessment was carried out after 3 weeks of incubation using an illuminator in a dark room. Fertile eggs were returned to the incubator, while non-fertile eggs were discarded. Eggs were candled again at day 39 of incubation to ascertain embryo viability and were then transferred to the hatcher for hatching at a temperature of 35.9ºC and a relative humidity of 40%. All non-hatched eggs were opened at day 42 to investigate the cause of hatching failure.

Production records:

A record of daily activity was made on specific data sheets. The recorded data included egg production, incidence and causes of egg defects, fertility, hatchability and embryonic mortality rates. The persistency of egg laying was also compared between the original breeders and their descendants, the new breeders. These data included the records of five production seasons (1998 – 2002) in Farm A and two seasons (2002 and 2003) in Farm B.

Statistical analysis:

The differences between group means were evaluated by Student's t-test. Probability values of $P< 0.05$ were considered significant.

Results

Egg production:

Ostrich egg production in Farm A and Farm B is shown in Table I. Eggs produced in the first three seasons in Farm A were laid by the original parent stock (N=268) while eggs produced in the following two seasons (2001 and 2002) included eggs laid by new breeders that were hatched in the Farm (N=168). In the first three seasons (1998, 1999 and 2000), the mean egg production per season was 1.2, 7 and 23 eggs per female, respectively. The new breeders started egg laying at the 19th month, with an average egg production of 12 eggs per female in the first season.

In Farm B, total egg production showed an increase from 3122 eggs in 2002 season to 7924 eggs in 2003 season with an increase of 153.8%. The mean egg production was 35.2 eggs per female in the last season (2003) compared to 13.5 eggs per female in 2002 season. However, the number of layers had dropped from 231 to 225 females.

Table I: Monthly frequency of ostrich egg production in Farm A and B.

Month	Monthly egg production						
	Farm A					Farm B	
	1998	1999	2000	2001	2002	2002	2003
Jan.	2	55	8	504	208	0	93
Feb.	13	152	86	371	242	34	261
Mar.	26	329	545	791	931	122	876
April	75	360	1043	1102	1514	332	1737
May	105	437	1230	1329	1920	609	1716
June	53	134	822	962	990	425	1095
July	25	175	511	553	293	582	931
August	0	95	269	102	424	440	526
Sep.	6	34	410	382	526	302	689
Oct.	7	6	339	651	291	276	0
Nov.	3	0	143	207	1246	0	0
Dec.	7	1	342	53	1770	0	0
Total	**322**	**1778**	**5748**	**7007**	**10355**	**3122**	**7924**

In both farms, egg laying started in January and February and the number of laid eggs increased gradually to reach the peak in April or May before it dropped to the minimum in November and December.

Ostrich egg defects:

There were 2044 defective ostrich eggs out of 21221 eggs examined in the two farms in the production seasons studied giving a crude rate of egg defects of 9.6%. The causes of egg defects and the relative prevalence of each cause are summarized in Table 2. As the number of laid eggs increased the number and percentages of defective eggs also increased. Most of the defective eggs in Farm A (34.5%) had sizes below the acceptable level for incubation (undersized) whereas for Farm B most of the defective eggs (43.9%) had holes in the shells.

Table 2: Causes and relative frequencies of egg defects in Farm A and B (N=2044).

Cause of defect	Defective eggs			
	Farm A		Farm B	
	No.	%	No.	%
Holes	430	26.9	197	44.1
Undersize	551	34.5	21	4.7
Chalky eggs	260	16.3	47	10.5
Cracks	128	8.0	37	8.3
Dirty shell	118	7.4	31	6.9
Rough shell	45	2.8	110	24.6
Oversize	34	2.1	0	0
Elongated eggs	31	2	4	0.9
Total	**1597**		**447**	

The original breeders showed sustained level of egg production which continued for a long duration in contrast to the new breeders which showed an unsustained and non-persistent pattern of egg laying. For both original and new breeders, August witnessed the lowest egg production while September and October showed a slight increase in egg laying before it dropped again towards the end of the season in December (Fig. 1).

Fertility:

Fertility rates of breeding ostriches in both Farms are shown in Table 3. Low fertility was observed in the first production season in Farm A (32.4%) compared to the following three seasons [55.6%, 60.7% and 61.2% (*P*=0.001)]. The fertility rate of the incubated eggs was lowest (36.5%) at the beginning of the breeding season, then improved with progress of the season (67.6%) before it dropped again (47.7%) at the end of the season**.**

In Farm B, the mean fertility rate for the 2003 season (66.6%) was generally higher than that for the 2002 season (50.2%). Moreover, the overall mean fertility rate of Farm B ostriches (68.6%) was generally higher than that of Farm A (52.5%), although none of those differences were significant (*P*>0.05).

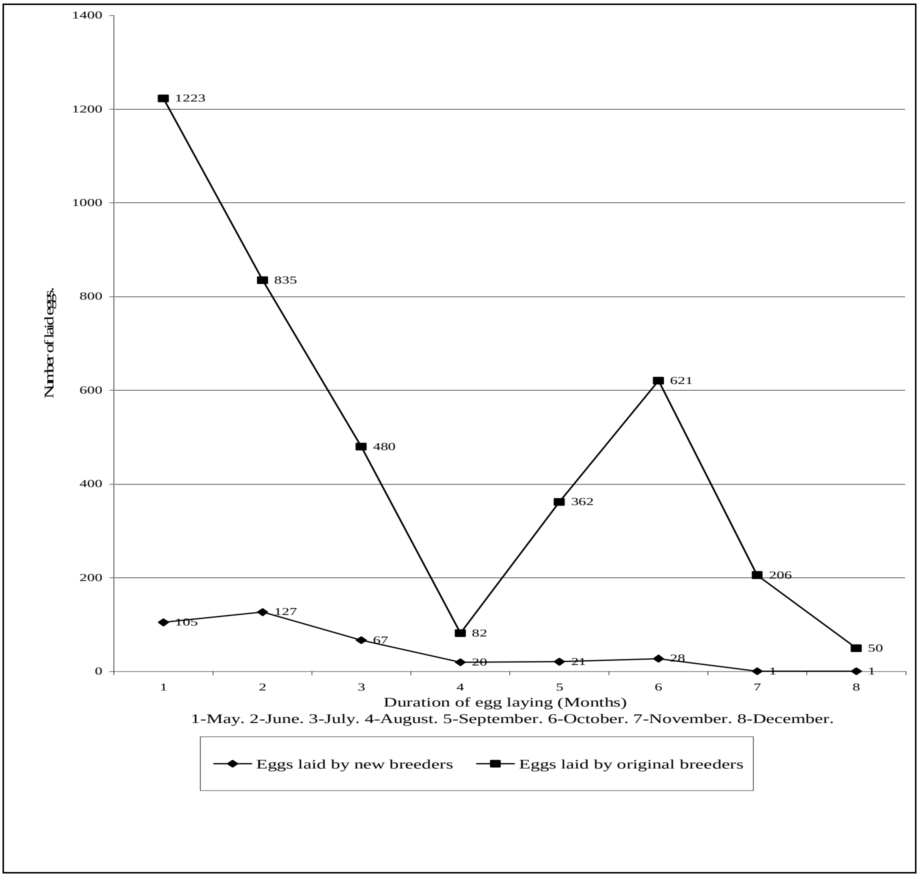

Fig. 1: **Persistency of ostrich egg laying in Farm A**.

Hatchability:

The hatchability rates of ostrich eggs in farms A and B are shown in Table 4. Ostriches in Farm A had a low overall mean fertility rate (52.5%) for the four seasons (1998 – 2001) when compared to the overall mean hatchability rate of the fertile eggs (75%) throughout the four seasons (p<0.05). The hatchability of incubated eggs declined towards the mid and the end of the production season. The overall mean hatchability rate of ostrich eggs in Farm A (75%) was generally higher than that of Farm B birds (67.3%) but the difference was insignificant (P>0.05).

Embryonic mortality:

Farm A and Farm B had crude embryonic mortalities of 25% and 32.7%, respectively. The incidence of early and late embryonic mortalities in Farm A ostrich eggs is presented in Table 5. The majority of embryonic mortality (61.9%) was in late developmental stages (last two weeks of incubation) whereas 38.1% mortality occurred during early embryonic development [first four weeks of incubation (P<0.05)].

Table 3: Fertility rates of ostrich eggs in Farm A and B.

Month	Fertility rates (%)					
	Farm A				Farm B	
	1999	**2000**	**2001**	**2002**	**2002**	**2003**
Jan.	14.29	No eggs	49.71	54.01	No eggs	No eggs
Feb.	21.74	36.47	53.68	47.92	No eggs	No eggs
Mar.	27.07	42.18	52.57	50.89	No eggs	No eggs
April	35.06	45.20	57.11	57.50	39.16	70.31
May	37.23	56.70	61.87	60.04	50.90	79.57
June	46.99	64.44	62.55	68.14	50.82	66.77
July	42.18	65.03	69.30	65.85	50.69	62.18
Aug.	51.21	67.56	61.26	68.48	54.77	60.70
Sep.	15.62	65.17	65.92	72.04	52.65	60.17
Oct.	No eggs	63.34	60.53	66.67	52.54	No eggs
Nov.	No eggs	57.85	66.22	No eggs	No eggs	No eggs
Dec.	No eggs	47.68	67.35	No eggs	No eggs	No eggs
SMFR	32.4	55.6	60.7	61.2	50.2	66.6
OFRs	**52.5 %**				**68.6 %**	

SMFR=Season mean fertility rate; OFRs= overall fertility rates

Table 4: Monthly frequency of hatched ostrich chicks and hatchability (%) in Farm A and B.

Month	Number of chicks and hatchability (%) of ostrich eggs											
	Farm A								Farm B			
	1999		2000		2001		2002		2002		2003	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Jan.	0	83.3	0	0	81	78.2	21	81.1	0	0	0	0
Feb.	3	70	0	78.1	146	86.3	39	84.1	0	0	0	0
Mar.	10	74.1	10	91.9	153	90.2	48	83.3	0	0	45	79.9
April	41	80.9	71	90.9	171	75.1	169	83.8	15	83.1	50	83.8
May	82	75.0	255	84.7	412	61.6	427	84.2	19	80.7	390	78.0
June	102	57	419	79.7	449	59.9	667	87.5	254	80.1	555	72.0
July	74	59.7	555	76.5	596	44.3	785	80.2	188	73.2	628	47.1
Aug.	32	50.8	395	92.8	394	63.2	311	84.5	207	61.0	200	54.0
Sep.	44	60	129	94.5	146	51.7	45	81.6	152	45.9	144	60.8
Oct.	0	0	155	93.1	71	65.2	249	54.8	104	49.0	112	64.3
Nov.	0	0	216	87.1	274	51	141	80.3	80	68.5	19	62.2
Dec.	0	0	141	88.2	248	48.5	37	81.1	19	66.9	0	0
Mean hatchability	**393 (67.9%)**		**2346 (87.1%)**		**3141 (64.6%)**		**2939 (80.5%)**		**1038 (67.6%)**		**2143 (66.9%)**	
Overall mean hatchability	**75%**								**67.3%**			

Table 5: Embryonic mortality in ostrich eggs in Farm A (1999 - 2002).

Season	Dead embryos	Early mortality		Late mortality	
		No.	%	No.	%
1999	184	87	47.3	97	52.7
2000	384	141	36.7	243	63.3
2001	337	147	43.6	190	56.4
2002	582	191	32.8	391	67.2
Total	**1487**	**566 (38.1%)**		**921 (61.9%)**	

Discussion

The successive increase in egg production of Farm A ostriches in the first three seasons throughout reflects the need for the imported breeding stock to adapt to the new environment. This is particularly so, since the birds were imported from a distant area with major climatic and ecological variations between the two habitats (Sauer and Sauer, 1966). In this study we reported, for the first time, 19 months as the age at which new ostrich breeders can start egg laying in Saudi Arabia yielding a mean of 12 eggs in their first production season.

Shanawany and Dingle (1999) and Shane and Tully (1996) reported a later age (two years) for maturity and start of laying by new ostrich breeders. The sharp increase in egg production in the third season compared to the second season in Farm B shows the gradual progress towards full maturity and productivity by the new breeders during their first few years of production life. Degen *et al.* (1994) have reported that, in the northern hemisphere ostriches egg laying occurs between March and September with peak numbers of laid eggs in May and June. The concentrations of plasma luteinzing hormone increased in February in both sexes and plasma testosterone concentrations in males increases in April (Degen *et al*, 1994). Egg production resumes its seasonal trend in the following relatively cooler months (September / October). The high ostrich egg production in the third season in Farm B (35.2 egg / female) by locally produced breeders, in Saudi Arabia, compared to egg production in the third season in Farm A breeders (23 egg / female), which were imported as mature birds, indicates that the local breeders performed better than the imported ones. This may be due to better adaptation (Shanawany and Dingle, 1999). The continuation of egg and chick production throughout the season, particularly in the last 2 – 3 seasons in Farm A, might indicate better adaptation of the breeders to the Saudi climate or that breeders had attained more maturity (Deeming and Ar, 1999). In this regard, the merits of importing mature stock at the point of lay should be weighed against the expected better performance of locally grown stock. The persistent and sustainable egg laying of the original breeders, compared to the new breeders, may be attributed to the full maturity of their reproductive systems (Deeming and Angel, 1996). The short breeding cycle of ostrich new breeders is attributed to immediate drop in gonadotrophins secretion to levels that are insufficient to support the reproductive hormonal requirements (Blache *et al*, 2001).

The high percentage of defective ostrich eggs in Farm A compared to Farm B is most probably a result of differences in the husbandry systems of the two farms. Breeders in Farm A were kept on communal pens and the new-laid eggs were subjected to damage by other birds more than those of Farm B where breeders were housed as couples in separate pens. The high incidence of oversized ostrich eggs in Farm A compared to Farm B might be due to genetic background. The high incidence of holes in Farm B ostrich eggs could be attributed to the rocky nature of the soil in that Farm. Abnormal or defective eggs are removed because of their reduced hatchability (Deeming and Ar, 1999; Gonzalez *et al*., 1999).

The high variability in fertility of ostrich eggs in different ostrich breeding countries is well documented (More, 1996; Murton and Westwood, 1997; Cloete *et al*, 1998; Deeming and Ar, 1999). The proportional successive improvement in fertility rates in Farm A ostrich eggs throughout the subsequent seasons could be due to the adaptation of the birds to the local environmental conditions besides the more maturity attained by the breeders (Deeming and Ar. 1999). Ostriches in this Farm had an average initial fertility rate of 32.4% in the first season, which rose to 55.6%, 60.7% and to 61.2% in the following seasons. This may be due to the fact that, females come into production earlier than the males. Murton and Westwood (1997) recorded a similar trend and attributed it to the slow increase in the production of luteinizing hormone and delayed increase in male plasma testosterone concentration at the beginning of the season. Moreover, the improved fertility of Farm B ostrich eggs in the second season, in contrast to the first season, could be due to the full maturity of male breeders (Fasenko and Hardin, 1992). Female breeders in communal pens could be mated by more males than in single pens leading to high fertility rates (Malecki and Martin, 2003). However, the low fertility rate of Farm A ostrich eggs compared to Farm B could be due to that dominant sterile or less fertile males would not allow other fertile, but less dominant, males to mate (Deeming, 1995; Gowe *et al*, 1993).

The hatchability of ostrich eggs was reported to be around 50% in Britain and 35% to 70% in South Africa (Horbanezuk and Sales, 1998). Hatchability in the present two farms ranged from 64.6% to 87.1%. The improved hatchability rate of Farm A ostrich eggs compared to Farm B may be attributed to the more efficient hatching equipment of Farm A. Farm A incubators had an in-built water chilling system, which controlled and regulated the internal temperature in contrast to Farm B incubation equipment which lacked this facility and led to difficulty in controlling the incubation temperature. Fluctuations in incubation temperature can lead to reduced hatchability rates (Sainsbury, 1992). The amount of egg weight loss during incubation as well as proper egg handling and storage are also important influential factors on hatchability of ostrich eggs (Nahm, 2001).

The negative influence of high ambient temperature on egg laying persistency is prominent, as manifested by the lowest number of ostrich eggs laid during August months in all seasons (Deeming and Angel, 1996). High ambient temperature is also incriminated as a cause of drop in fertility rates of ostrich eggs laid during July months (Gangwar, 1983). Moreover, the drop in hatchability pattern towards the mid of the season could be attributed to the negative effect of high ambient temperature on the efficiency of the incubating and hatching equipment (Deeming, 1996; Gangwar, 1983).

The high percentage of late embryonic mortality in ostrich eggs could be due to insufficient water loss during incubation. This produces a too small air cell which leads to difficulties in the hatching process, mainly due to suffocation (Horbanezuk and Sales, 1998; Ley *et al*, 1986). Some other workers, on the other hand, incriminated the vertical positioning method of the longitudinal axis of the eggs, which had been used in these two farms, as a cause of embryonic death. It has been claimed that horizontal positioning for the first 2 – 3 weeks followed by vertical positioning for the rest of the incubation period yield better hatchability results and reduce embryonic mortality (Smith *et al*, 1995). Yolk sac infection has also been blamed for late embryonic mortality due to contamination of hatching eggs with microbial agents which penetrate the egg shell leading to infection of the yolk sac (Huchzermeyer, 1998). Another main cause of early embryonic mortality is the delay in egg collection, leading to pre-incubation of eggs, particularly by male breeders. The subsequent cooling and storage of the pre-incubated egg leads to death of the developing embryo (Shane and Tully, 1996). Other possible causes of early embryonic mortality include poor quality eggs, poor storage conditions and incorrect incubation temperature (Deeming, 1997).

There are no previous studies in Saudi Arabia with which these findings can be compared although the Arabian ostrich (*Struthio camelus syriacus*) was once abundant in the deserts of Saudi Arabia. Heavy hunting of the Arabian subspecies resulted in its flocks fragmentation and had driven the remainder into remote inhospitable regions within the Arabian peninsula which ultimately resulted in its extinction by 1950s (Seddon and Khoja, 1998). Currently, the National Commision for Wildlife Conservation and Development (NCWCD) in Saudi Arabia is implementing a programme of captive breeding and reintroduction of the closest living relative of the

Arabian ostrich, the red neck *Struthio camelus camelus*, from Sudan. This relatively wild subspecies is adapted to hot arid conditions and it was hoped that birds released in Saudi Arabia will survive and breed in the bush although it has low productivity compared to other domesticated subspecies. Therefore, in efforts to utilize the emerging interest in commercial ostrich farming, Saudi investors have to rely either on foreign import of their initial breeding stock or on the locally grown stock generated from adapted subspecies such as *Struthio camelus* var *domesticus* which has proved its good performance during this study (Farm B records).

The results and conclusions derived from this study such as productivity indices, fertility and hatchability rates, can be of great importance to the ratite producers and researchers in Saudi Arabia. However, further research to optimize fertility and hatchability rates of ostrich eggs is recommended to get the maximum output of this developing industry.

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