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Commercial native laying hybrids developed in Turkey are comparable to foreign hybrids in terms of performance and cultural energy use efficiency

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The purpose of this study was to conduct an input-output analysis of various commercial layer hybrids. The Rhode Island Red I x Barred Rock I (Atak-S), Black Line x Blue Line (Atabey), Rhode Island Red II x Line 54 (Atak) together with Nick Chick and Brown Nick foreign hybrids were used. A total of 45 hens, nine from each hybrid, were placed individually into separate cages. The study covered a 49-week of period between 24 and 72 weeks. All the inputs, energy values of inputs and the energy value of products were calculated. Cultural energy expended for feed constituted more than half of the total cultural energy and it was highest for Atak-S (P<0.05). Energy use efficiency for protein defined as cultural energy expended per MJ protein energy was better for Nick Chick and worse for Atak-S (P<0.05). The Nick Chick showed better energy use efficiency, defined as the total cultural energy expenditure divided by energy output compared to Atak-S (P<0.05) and had similar values to those of the Atak, Atabey and Brown Nick (P>0.05). Results show that hybrids differ in terms of their cultural energy use efficiency and thus a suitable hybrid adapted to the region should be sought for sustainable laying hen production.

KEY WORDS: poultry/ sustainability/ hybrid/ performance/ energy input-output analysis

Because of the diminishing energy sources, high cost of energy production and pollution caused by fossil fuels it is necessary to use energy sources efficiently. The intensive use of energy increases the emission of carbon dioxide to the atmosphere, which results in global warming [Özkan *et al.* 2004]. The increase in the use of

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energy contributes not only to global warming, but also air pollution, acid rain and the depletion of the ozone layer. In order to reduce such environmental effects, a more efficient production with lower energy use must be developed [Dinçer *et al.* 2004]. In Turkey the agricultural sector ramks third in energy use after the industry and service sectors. The agricultural sector accounts for approximately 4% of the total energy use [Öztürk and Barut 2005].

In order to meet primary needs of the increasing population, an effective and productive agricultural system should be the priority. In accordance with various agricultural system analyses, knowledge on the use of various energy sources is essential along with the conservation of such resources as water, soil and biological resources to protect them for the next generations [Pimentel *et al.* 1999]. The increasing environmental problems reveal the reality of limited sources. Because of that, it is particularly important to use the resources efficiently. In view of the above, all the activities concerning sustainability should be examined closely [Koç 2002]. The sustainable and economical utilization of resources will ensure availability of these resources for a longer time. In sustainable production all the processes and technologies used should follow the ecologic cycles. All the necessary analyses should be done for people to have an adequate and balanced diet and a long-term sustainable agriculture [Camcı and Şahin 2005].

Sustainability in terms of energy use takes into consideration the use of all energy other than solar radiation, which is required to obtain a product. Additionally, production processes requiring intensive energy input should be streamlined and energy saving measures should be taken. Through such analyses, not only the energy needed for production is examined, but also the energy utilized by animals and humans is determined [Özkan *et al.* 2004].

Poultry production is an important sector in Turkish animal production and its share has increased recently. Due to the superior reproductive and performance traits of poultry, this production provides higher protein yield than other animal agricultural branches [Akbay 1985]. One of the ways to increase the production efficiency in layers is using suitable hybrids. The Poultry Research Station in Ankara developed 3 hybrids (2 brown and 1 white egg layer) adapted to conditions in Turkey. Durmuş *et al.* [2009] showed that their performance is comparable to that of foreign hybrids. There have been studies examining the performance of both hybrids developed in Turkey and foreign hybrids, but no research has examined cultural energy use efficiency of these hybrids. Thus the purpose of this study was to determine cultural energy use efficiency of layer hybrids and to incorporate this into the strategy for sustainability.

Material and methods

In the conducted study foreign hybrids of the Brown Nick, Nick Chick and Brown layer hens such as Rhode Island Red I × Barred Rock I (Atak-S), Rhode Island Red II × Line 54 (Atak) and the white layer such as Black × Blue (Atabey), which were derived by the Poultry Research Station in Ankara (Turkey) were used as the study material. Hybrids were transported to the Suleyman Demirel University Poultry Teaching & Research Facility when they were one-day old. All the required vaccinations were completed. When chicks reached the age of 17 weeks, 9 from each hybrid (thus totalling 45 chicks) were chosen at random and placed in individual cages where they were fed and kept. The size of each cage was 32 cm in width, 45 cm in length and 43 cm in height. Feed and water were offered *ad libitum*. During the first period which spanned from the 21st to the 40th weeks, and the second period between the 41st and 72nd week the laying hens received different feeds. The composition of the pelleted feed administered in the first and second period of the study are given in Table 1.

Table 1. Composition of the laying hen diet for periods

Ingredient	1st period – 21 and 40 weeks (g)	2nd period – 41 and 72 weeks (g)
Corn	400	418
Wheat	213.65	215.76
Full fat soybean	60	60
Soybean meal (%48 CP)	152	128
Sunflower meal (%32 CP)	50	50
Vegetable oil	16.89	5.2
Limestone	82.77	101.28
Dicalcium phosphate	15.84	13.17
D-L Methionine	2.43	2.06
L-Lysine	-	0.36
Threonine	0.72	0.47
Salt	3.5	3.5
Preliminary mixed vitamins*	1	1
Preliminary mixed minerals**	0.7	0.7
Antioxidants	0.5	0.5
Total	**1000**	**1000**
Metabolic energy (kcal/kg)	2800	2700
Crude protein, %	17	16

*Each 1kg of vitamin mixture contained 12.500.000 IU vitamin A, 5.000.000 IU vitamin D_3, 200.000 mg vitamin E, 4.000 mg vitamin K_3, 3.000 mg vitamin B_1, 8.000 mg vitamin B_2, 5.000 mg vitamin B_6, 40 mg vitamin B_{12}, 60.000 mg niacin, 12.000 mg calcium-D-pantothenate, 2.000 mg folic acid, 50 mg biotin and 150.000 mg vitamin C.
**Each 0.7 kg of mineral mixture contained 100.000 mg Manganese, 150.000 mg zinc, 100.000 mg iron, 20.000 mg copper, 1.500 mg iodine, 500 mg cobalt, 200 mg selenium, 1.000 mg molybdenum and 50.000 mg magnesium.

When chicks reached the age of 24 weeks, data collection was started and it was completed in the 72nd week. In order to collect correct data concerning the total amount of inputs, which was mostly the feed consumed, chicks were placed in individual cages. The data collected throughout the study included: survival rate, egg yield, egg weight, feed consumption, electricity used in the poultry house, labor during feeding and care, the distance, from which the feed was transported, the lighting program of the poultry house and the period of time fans worked for forced ventilation. In

Table 2. Cultural energy of the input and output

Input	MJ/Unit	References
Corn (kg)	5.13	Sainz [2003]
Wheat (kg)	4.03	Sainz [2003]
Rich soy (kg)	5.90	Sainz [2003]
Soybean meal - %48 CP (kg)	5.61	Sainz [2003]
Sunflower meal - %32 CP (kg)	1.3	Sainz [2003]
Vegetable oil (kg)	82.0	Pimentel and Patzek [2005]
Limestone (kg)	0.37	Sainz [2003]
Dicalcium phosphate (kg)	9.99	calculated
D-L Methionine (kg)	29.45	calculated
L-Lysine (kg)	32.22	calculated
Threonine (kg)	20.83	calculated
Salt (kg)	0.37	Sainz [2003]
Preliminary mixed vitamins (kg)	41.38	calculated
Preliminary mixed minerals (kg)	0.37	calculated
Antioxidants (kg)	13.68	calculated
1st period feed (kg)	5.90	calculated
2nd period feed (kg)	4.85	calculated
Labor (hour)	2.28	Cook *et al.*[1980], Yaldız *et al.* [1993]
Water (m^3)	0.63	Yaldız *et al.* [1993]
Electricity (kw/hour)	1.92	Singh [2002]
Transportation (MJ/km)	0.000023	Cook *et al.*[1976]
Output		
Egg (kg)	6.32	Roe *et al.*[2002]

the scope of those inputs the cultural energy used was calculated by multiplying the amount of individual input used and the unit energy value of that input are given in Table 2.

Cultural energy used for the feed for the hybrids was derived from their individually recorded feed consumption and the corresponding values from literature reported in Table 2. Transportation energy was also included in the analysis and hauling eggs to the local market and feeds from the feed manufacturer accounted for the transportation energy. When calculating transportation energy, the amount of eggs hauled (kg) and amounts of feed bought (kg) and the distance (km) between the farm and the local market and the feed manufacturer were considered. Total energy expended was the sum of energy expended on the feed, electricity, transportation and miscellaneous purposes. When calculating energy deposited in eggs, it was assumed that egg content would have 6.32 MJ per kg of unshelled eggs (Tab. 2).

In order to calculate the energy output for each laying hen, the total egg mass, which is obtained by multiplying the total number of eggs laid with egg weight and the energy value of the egg (which is 1. 6.32 MJ per kg of an unshelled egg). The energy required to produce a unit of protein was calculated by dividing the total cultural energy expended by egg protein energy content. For this purpose it was assumed that the energy value of 1 g of protein was 17kJ. Efficiency defined as the cultural energy input per energy output was calculated by dividing the total cultural energy expended by the energy deposited in an egg.

Statistical analysis

The data were analyzed using one-way analysis of variance under the General Linear Model (GLM) procedure of SAS [1999]. Tukey's test was used to compare hybrid means. As for the significance level (P<0.05) was accepted as statistically significant.

Results and discussion

Cultural energy (CE) input and output for hybrids are given in Table 3. Atak-S had a higher CE expended on feed than Atak, Brown Nick, Atabey (P<0.05), while it had similar values with Nick Chick (P>0.05), which was intermediate (Tab. 3). Since the hybrids received the same diet in the experiment, this difference in CE expended on feed is solely a function of feed consumption. As could be observed in Table 4, Atak-S showed a higher average feed consumption than Atak, Brown Nick, Atabey (P<0.05) and a similar average feed consumption as Nick Chick (P>0.05). In general, feed consumption was related to body weight of the chicks with the exception of Nick Chick, which had a relatively lower body weight and higher feed consumption. Leeson and Summers [2005] indicated that brown layers have a higher energy requirement for maintenance than white layers. Since the maintenance requirement is related to the average body weight of chicks this may explain the results for Atak-S, Atak and Brown Nick, which are brown layers having a higher feed consumption. In this context it would be expected Nick Chick, which is a white layer having a lower feed consumption than brown layers, but the exact reason why Nick Chick tends to have a higher feed consumption than Atak, while the level for Brown Nick is not known.

Table 3. Averages and standard deviations (in parenthesis) for Cultural energy (CE) input, output and CE use efficiency in hybrids of laying hens

Item	Atak-S	Atak	Brown Nick	Atabey	Nick Chick
CE expended for feed (MJ)	192.12^{a} (7.28)	174.01^{b} (15.55)	171.40^{b} (10.17)	166.75^{b} 11.27)	178.31^{ab} (11.02)
CE for electricity (MJ)	70.29^{a}	70.29^{a}	70.29^{a}	70.29^{a}	70.29^{a}
CE for transportation (MJ)	17.07^{a} (0.64)	15.43^{b} (1.36)	15.13^{b} (0.92)	14.75^{b} (0.97)	15.78^{ab} (1.05)
CE for miscellaneous, MJ	10.25^{a}	10.21^{a}	10.21^{a}	10.21^{a}	10.21^{a}
Total CE expended (MJ)	289.60^{a} (7.91)	269.83^{b} (16.91)	266.93^{b} (11.09)	261.90^{b} (12.24)	274.76^{ab} (3.53)
Energy content of total egg mass (MJ)	90.40^{ab} (10.48)	87.35^{b} (13.16)	85.61^{b} (10.81)	91.25^{ab} (7.69)	101.51^{a} (5.69)
Energy use efficiency for protein (MJ input/MJ protein energy output)	6.37^{a} (0.79)	6.20^{ab} (1.06)	6.21^{ab} (0.77)	5.66^{ab} (0.38)	5.32^{b} (0.26)
Energy use efficiency (MJ input/MJ output)	3.24^{a} (0.40)	3.16^{ab} (0.54)	3.16^{ab} (0.39)	2.88^{ab} (0.19)	2.71^{b} (0.13)

^{1b}In rows means bearing different superscripts differ significantly at P<0.05.

The average CE expended on feed for all the hybrids constituted 64.76% of total cultural energy expenditure. Research conducted on broilers, beef cattle, dairy cattle and sheep also showed that CE expended on feed was the greatest contributor to total CE expenditure [Koknaroglu and Atılgan 2007, Koknaroglu *et al.* 2007a, Koknaroglu *et al.* 2007b, Koknaroglu 2010, Koknaroglu and Hoffman 2019].

Cultural energy expended for electricity is given in Table 3. Cultural energy expended for electricity included electricity consumed by lighting and forced ventilation. Electricity expenditure was adjusted by considering the full capacity of the poultry house. Since chicks were kept in individual cages adjacent to each other electricity expenditure was identical for all the chicks.

Cultural energy expended for transportation was highest for Atak-S and differed from Atak, Atabey and Nick Brown (P<0.05, Tab. 3). The values for Nick Chick were intermediate and did not differ from those of the other hybrids (P>0.05). The reason for Atak-S to have a higher CE expenditure on transportation is due to the higher feed consumption and relatively greater egg weight (Tab. 4). Cultural energy expended for miscellaneous purposes is given in Table 3. Cultural energy expended for miscellaneous purposes included labor and water. All the hybrids had similar CE expenditure for miscellaneous purposes, since they had the same amount of labor spent and nearly identical water consumption.

Table 4. Averages and standard deviations (in parenthesis) of performance traits in the studied populations

Item	Atak-S	Atak	Brown Nick	Atabey	Nick Chick
Initial body weight (g)	1624.93^{a}	1395.50^{c}	1603.23^{b}	1207.53^{e}	1282.86^{d}
Final body weight (g)	2066.90^{a}	1755.30^{c}	1939.33^{b}	1532.23^{e}	1629.23^{d}
Total number of egg laid (A)	245^{ab} (29.01)	250^{ab} (38.04)	228^{b} 29.45)	269^{a} (22.50)	281^{a} (14.71)
Average egg weight (g) (B)	65.59^{a} (0.37)^{a}	62.13^{b} (0.30)	66.83^{c} (0.59)	60.34^{d} (0.20)	64.22^{e} (0.30)
Total egg mass (kg) (A*B)	16.10^{ab} (1.86)	15.55^{b} (2.34)	15.24^{b} (1.92)	16.24^{ab} (1.37)	18.07^{a} (1.01)
Average feed consumption (g)	106.66 (3.98)	96.39^{b} (8.52)	94.53^{b} (5.73)	92.17^{b} (6.06)	98.58^{ab} (6.55)
Feed conversion (kg feed/kg egg)	2.35^{a} (0.30)	2.21^{ab} (0.38)	2.19^{ab} (0.27)	1.99^{b} (0.13)	1.91^{b} (0.11)

^{abcde}In rows means bearing different superscripts differ significantly at P<0.05.

The total CE expenditure, which was the sum of CE expended on feed, transportation, electricity and miscellaneous purposes is provided in Table 3. The total cultural energy expenditure was highest for Atak-S and differed from those of Atak, Atabey and Nick Brown (P<0.05, Tab. 3). Nick Chick proved to be an intermediate breed and did not differ from the other hybrids (P>0.05). Differences in the total CE expenditure follows the same trend in CE expended for feed. Since CE expended on feed constitutes most of the total CE expenditure (64.76%), such a result could have been expected.

The total egg mass is a result of multiplication of the total number of eggs laid by the average egg weight and it is given in Table 4. Nick Chick had a greater total egg mass than Atak and Brown Nick (P<0.05) and had similar values as Atak-S and Atabey (P>0.05). Energy content of the total egg mass is a product of total egg mass multiplied by energy of an egg provided in Table 2. Nick Chick had a higher energy content of total egg mass than Atak and Brown Nick (P<0.05) and had similar values with Atak-S and Atabey (P>0.05).

Energy use efficiency for protein, which is cultural energy expended per MJ protein energy output, is given in Table 3. Nick Chick had a better energy use efficiency for protein than Atak-S (P<0.05) and had similar values as Atak, Atabey and Brown Nick (P>0.05, Tab. 3). Since animal origin protein intake is becoming more important for human nutrition, this explains the importance of more efficient hybrids for sustainable animal production. Koknaroglu *et al.* [2006] when examining the effect of breed on cultural energy expenditure in lamb production found that the Suffolk breed had better energy use efficiency for protein than the Texel and Columbia breeds. Energy use efficiency for protein in this study was better than that of dairy cattle, sheep and beef cattle and worse than broilers, thus showing the efficiency of laying hens converting CE to protein energy output [Koknaroglu and Atılgan 2007, Koknaroglu *et al.* 2007a, Koknaroglu 2010, Koknaroglu *et al.* 2006, Pimentel 2004, Koknaroglu 2008]. As it was indicated by Koknaroglu and Atılgan [2007], even though broilers required less cultural energy per unit protein energy, their dependence on grain for feeding places them in competition with humans. This is also the case for laying hens, since they consume mostly concentrate feed, which may also be consumed by humans. Energy use efficiency defined as the total cultural energy expenditure divided by energy output is presented in Table 3. This shows the mega calorie of cultural energy expended for mega calorie of food energy. Nick Chick had a better energy use efficiency than Atak-S (P<0.05) and had similar values as Atak, Atabey and Brown Nick (P>0.05,Tab. 3). A white layer Atabey had the second best energy use efficiency value after Nick Chick, which is also a white layer. This shows that white layers are better energy converters than brown layers. The reason for Nick Chick in this study to have a better energy use efficiency is that it had numerically a higher total number of eggs laid with a comparable average egg weight, thus resulting in a trend towards a higher total egg mass (Tab. 4). Atabey tended to exhibit a better energy use efficiency due to its comparable total number of eggs laid and its lower feed consumption resulting in a lower CE expended for feed. Similar results in terms of performance of layers were found by Mızrak *et al.* [2007a, 2007b), who reported that white laying hens had a higher number of eggs laid. In a study comparing production performance of different strains of laying hens, Singh *et al.* [2009] found that white layers were characterized by a higher number of eggs laid, lower feed consumption and better feed conversion than brown layers. Results showed that energy use efficiency of hybrids reported in Table 3 follows the feed conversion of hybrids reported in Table 4, indicating that feed conversion is the most important factor determining energy use efficiency. Similar results were reported by Demircan and Koknaroglu [2007], who found that cattle exhibiting a better feed efficiency had also a better energy use efficiency. Results showed that energy use efficiency recorded in this study was better than for other ruminant species, implying that laying hens are efficient converters of energy into food energy [Koknaroglu *et al.* 2007a, Koknaroglu *et al.* 2007b, Koknaroglu 2010, Koknaroglu *et al.* 2006, Pimentel 2004, Koknaroglu, 2008]. Pimentel *et al.* [2006] reported that among the livestock systems evaluated, broiler chicken production is the most energy efficient, with 1 MJ of broiler protein produced with an input of 4 MJ of fossil fuel energy. The review of life cycle assessment studies undertaken by DEFRA, [2013] showed that energy used in the production of eggs, expressed as MJ/kg, ranged between 27.2 and 31.3, with an average of 29.2 MJ/kg. Results show that when choosing a laying hen hybrid, sustainability of the production in terms of energy use efficiency should be considered and white layers were found to be more efficient in converting CE to energy into food compared to brown layers.

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