The effect of dietary Jerusalem artichoke (*Helianthus tuberosus* L.) on performance, egg quality characteristics and egg cholesterol content in laying hens

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ABSTRACT: This research was carried out to determine the effect of Jerusalem artichoke (JA) with or without 5, 10% vetch (V) supplementation on performance, egg quality characteristics and egg cholesterol content. In the study, seventy-five 25 weeks-old commercial white laying hens were randomly divided into one control and 4 treatment groups each containing 15 hens. Control group was fed basal diet without JA or V. Treatment group 1, 2, 3 and 4 were fed diets containing 5% V, 5% JA, 5% JA + 5% V and 10% JA + 10% V, respectively. The feeding period lasted 16 weeks. In the study, it was determined that dried-ground JA contained dry matter, crude protein, ether extract, crude fibre, crude ash, inulin and metabolizable energy (ME) at the level of 93.30, 10.02, 0.36, 5.64, 9.05, 15.80% and 3 060 kcal/kg, respectively. At the end of the study, live weight was lower by 4.36–10.09% in the treatment group 10% JA + 10% V compared with the other groups, but feed efficiency was improved in this group. There were statistically significant differences between the groups in egg quality characteristics ($P < 0.05$, $P < 0.001$). Egg production was not affected by supplementation of 5, 10% JA with or without 5, 10% V supplementation. Egg yolk cholesterol and total cholesterol content were not different in the groups ($P > 0.05$). As a result, the addition of JA with or without V has no adverse effect on performance and egg quality in hens.

Keywords: Jerusalem artichoke; laying hen; egg production; egg quality characteristics

Rising opposition to the prophylactic use of antibiotics as livestock feed additives has prompted the search for effective alternatives (Cromwell, 2000). Currently low concentrations of antibiotics are included in diets to enhance animal health and improve performance. Certain dietary oligosaccharides, such as inulin and oligofructose, are considered as prebiotics and they are possible substitutes for antibiotics (Best, 2000). Inulin and oligofructose are present naturally in several fruits and vegetables like Jerusalem artichoke, chicory, onion, garlic, banana and others. Jerusalem artichoke is a plant that can serve as an alternative source of carbohydrates. The tubers contain 14–15% inulin (Patkai and Barta, 2002).

Fructooligosaccharides (FOS) and inulin are composed of short chains of fructose molecules (Roberfroid, 1993). Administration of FOS or inulin can serve as food (Cieoelik et al., 2002) for and increase the number of bifidobacteria, lactobacilli and certain butyrate-producing bacteria (Hold et al., 2003) in the colon while simultaneously reducing the population of harmful bacteria such as the Clostridium perfringens group (Gibson et al., 1995). Other benefits noted with FOS or inulin supplementation include increased production of beneficial short-chain fatty acids such as butyrate, increased absorption of calcium and magnesium, and improved elimination of toxic compounds (Tomomatsu, 1994; van den Heuvel et al., 1999).

Supported by the Ankara University Research Fund (Project No. 97 10 00 02).

Table 1. The ingredients of experimental rations (%)

Ingredient	Control group	Treatment groups			
		5% V	5% JA	5% JA + 5% V	10% JA + 10% V
Barley	36.50	36.00	34.00	34.30	31.30
Maize	30.00	28.80	28.00	26.00	22.00
Soybean meal	19.00	16.00	18.80	15.50	12.50
Poultry meal	3.20	3.00	3.00	3.00	3.00
Vetch	–	5.00	–	5.00	10.00
Jerusalem artichoke (dried)	–	–	5.00	5.00	10.00
Dicalcium phosphate	1.60	1.50	1.50	1.50	1.50
Limestone	9.00	9.00	9.00	9.00	9.00
Salt	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10	0.10
Vitamin-mineral premix*	0.35	0.35	0.35	0.35	0.35

*supplied per kilogram of diet: vitamin A, 12 000 IU; vitamin D3, 1 200 IU; vitamin E, 15 mg; vitamin K3, 3 mg; vitamin B1, 3 mg; vitamin B2, 5 mg; vitamin B6, 4 mg; vitamin B12, 15 mg; niacin, 18 mg; Ca-D-pantothenate, 6 mg; folic acid, 0.6 mg; vitamin C, 20 mg; choline chloride, 250 mg; manganese, 100 mg; zinc, 60 mg; cobalt, 3 mg; iodine, 1.8 mg; copper, 5 mg; iron, 40 mg

Recently Yusrizal and Chen (2003) indicated that supplementation of oligofructose and inulin improved body weight gain and feed conversion ratio of female broilers. Chen et al. (2005) reported that dietary oligofructose and inulin increased ($P < 0.05$) egg production and feed efficiency of layers without impairing egg quality. In addition, Chen and Chen (2004) observed that oligofructose or inulin promoted bird's health and improves eggshell quality.

This research was carried out to determine the effect of Jerusalem artichoke (as a source of inulin) on performance, egg quality characteristics and egg cholesterol content in laying hens.

MATERIALS AND METHODS

Twenty-five-weeks-old 75 commercial white laying hens were used in the study. They were divided into one control and 4 treatment groups each containing 15 hens. The feeding period lasted 16 weeks.

Three birds were housed per 45 × 45 × 45 cm wire cage, given feed and water for *ad libitum* intake throughout the experiment and subjected to a photoperiod of 17 h light/day. Its temperature was maintained between 16 and 25°C.

The control group was fed a basal diet based on barley, maize, soybean meal and poultry meal. The diets fed to hens of treatment group 1, 2, 3 and 4 contained 5% vetch (V), 5% Jerusalem artichoke (JA), 5% JA + 5% V and 10% JA + 10% V, respectively. Since tannin in vetch (7.30% tannin) has a constipation effect, vetch was added to the experimental diets to compensate the diarrhoeal effect of inulin in JA. Tannin content in vetch was determined by Folin-Denis Method from AOAC (1990). Dried at 60°C and ground, JA was added to the rations. Ingredients of the rations used in the trial are shown in Table 1.

Chemical analyses of feed ingredients and rations were done by standard AOAC (1990). ME values of rations were calculated according to Carpenter and Clegg (1956). ME value for poultry in JA was calculated according to Titus and Fritz (1971). Inulin in JA and rations was determined according to Strepkov Phosphomolybdic-Permanganate Volumetric Method (Winton and Winton, 1947). Egg cholesterol content was measured by the spectrophotometric method of Washburn and Nix (1974) using a diagnostic kit (Sigma, 1998).

Body weights were recorded at the beginning and at the end of the study to determine body weight changes. Feed consumption was calculated on a weekly basis throughout the experiment. The number of eggs was recorded daily and egg weights were recorded weekly having waited at a room temperature for 24 h. Eggshell quality measurements were done at 4-week intervals, between 25 and 41 weeks of age. Ten eggs were collected from each

Table 2. Nutrient content (%), metabolisable energy value (kcal/kg) and inulin content (%) of Jerusalem artichoke and experimental rations

	Dried JA	Vetch	Control group	Treatment groups			
				5% V	5% JA	5% JA + 5% V	10% JA + 10% V
Metabolisable energy	3 060*	2 825**	2 654* (2 750**)	2 653* (2 828**)	2 656* (2 481**)	2 651* (2 600**)	2 648* (2 456**)
Dry matter	93.30	90.90	94.21	94.22	94.21	94.04	94.47
Crude protein	10.02	31.10	16.90	16.70	16.21	17.00	16.63
Ether extract	0.36	0.50	3.36	3.30	2.96	3.02	3.81
Crude fibre	5.64	5.85	3.78	3.85	3.84	3.90	3.97
Crude ash	9.05	8.60	11.60	9.82	11.87	13.10	12.63
Nitrogen free extract	68.23	44.85	58.57	60.55	59.33	57.02	57.43
Calcium	0.30	–	3.40	3.75	3.10	3.75	3.65
Phosphorus	0.18	–	0.63	0.60	0.61	0.60	0.65
Inulin	15.80	–	0.90	1.20	1.60	1.86	2.70

*it was determined according to Titus and Fritz (1971)

**it was determined according to Carpenter and Clegg (1956); also ME value of feed ingredients was determined by the same method

group to determine exterior and interior egg quality characteristics. Egg breaking strength, yolk index, albumen index, Haugh unit score and shell thickness (Card and Nesheim, 1972) were measured. Yolk colour score (Vuilleumier, 1969) was measured with Roche Yolk Colour Fan.

The experiment was designed as Completely Randomised Blocks and Analysis of Variance was applied to the design in SPSS (1999). The significance of differences between treatment means was tested by Duncan's Multiple Range Test, egg production in the groups was evaluated by Chi-Square Test (Snedecor, 1974).

RESULTS AND DISCUSSION

Crude nutrient content, metabolisable energy value and inulin content of Jerusalem artichoke and experimental rations are given in Table 2. Egg production, feed intake, feed conversion and body weight of the groups are shown in Table 3. Mortality was not observed in the groups during the experimental period. Mean body weights at 41 weeks of age in control and treatment groups 5% V, 5% JA, 5% JA + 5% V and 10% JA + 10% V were found to be 1 694.29, 1 700.07, 1 646.43, 1 598.33 and 1 528.57 g, respectively (Table 3). Mean body weight of the treatment group 10% JA + 10% V was lower by 4.36–10.09% than the mean weight of other groups at 41 weeks of age. This might result from 10% V addition. Similarly, Ergun et al. (1986) and Dikicioglu et al. (1996) reported that 10% V supplementation to broiler rations decreased body weight. These results contradict the work of Ammerman et al. (1989), who reported that dietary oligofructose insignificantly ($P > 0.05$) increased final body weights in broilers. On the other hand, Chen et al. (2005) recorded a general decrease in live weight between 57 and 61 weeks in laying hens either receiving inulin or not.

Daily feed intake in the control and treatment groups 5% V, 5% JA, 5% JA + 5% V, 10% JA + 10% V was found to amount to 117.29, 116.44, 116.92, 113.57 and 116.38 g/day (Table 3), respectively. Feed conversion ratio in the control and treatment groups 5% V, 5% JA, 5% JA + 5% V, 10% JA + 10% V was 1.64, 1.62, 1.65, 1.56 and 1.59 kg feed/dozen egg production (Table 3). In the present experiment, feed intake for per dozen egg production was decreased by the addition of 5% JA + 5% V and 10% JA + 10% V. Namely, feed conversion was

Table 3. Effects of Jerusalem artichoke on performance

Treatment groups	Egg production[1] (% hen-day) $\bar{x}$ $S_{\bar{x}}$	Feed intake[1] (g/hen/day)	Feed conversion[1] (kg/doz)	Body weight at 25 weeks (g) $\bar{x}$ $S_{\bar{x}}$	Body weight at 41 weeks (g) $\bar{x}$ $S_{\bar{x}}$
Control	86.40 ± 1.20	117.29	1.64	1444.66 ± 55.53	1694.29^{ab} ± 43.20
5% V	85.18 ± 0.87	116.44	1.62	1477.00 ± 33.93	1700.07^{a} ± 44.35
5% JA.	86.85 ± 0.96	116.92	1.65	1454.00 ± 52.45	1646.43^{ab} ± 52.88
5% JA + 5% V	87.52 ± 1.18	113.57	1.56	1467.14 ± 55.58	1598.33^{ab} ± 33.92
10% JA + 10% V	88.16 ± 1.96	116.38	1.59	1451.33 ± 44.30	1528.57^{b} ± 31.21
F-value	0.77^{-}			0.07^{-}	2.93*
X^2	6.53^{-}				

^{a,b}means with different superscripts differ significantly (P < 0.05)

[1]means for a 16-week period

improved by the addition of JA to the rations. Similarly, Chen et al. (2005) reported that the supplementation of oligofructose or inulin to laying hen rations did not influence feed consumption but the hens that received oligofructose and inulin produced more eggs than the birds fed a control diet. Therefore, feed conversion ratio was improved by oligofructose or inulin addition. Several researches showed that dietary oligofructose in broilers (Ammerman et al., 1989) and probiotics in laying hens (Krueger et al., 1977; Mohan et al., 1995) improved feed efficiency. Krueger et al. (1977) and Abdularahim et al. (1996) reported that the improvement of microbial ecology in layers' intestine by using probiotics might enhance their health and improve feed efficiency.

Egg production was not significantly (P > 0.05) affected by the supplementation of JA with or without V. Hence, dietary JA at the level of 5 and 10% caused higher egg production. This increase was especially pronounced in the treatment group 10% JA + 10% V (by 2% compared with the control group). These results agree with the reports of Chen et al. (2005), who determined that the addition of 1.0% oligofructose and 1.0% inulin to the layer diets for 4 weeks increased (P < 0.05) egg production by 13.35% and 10.30%, respectively, compared to the control group.

Egg weight, egg breaking strength, shell weight and shell thickness are given in Table 4. Egg weight was significantly (P < 0.001) higher after the addition of 5% JA with or without 5% V compared with the group 10% JA + 10% V. Chen et al. (2005) observed an increase in cumulative egg weight after the addition of oligofructose (1st week, 7.93; overall, 12.50%) and inulin (1st week, 8.18%: overall 10.96%), while no difference (P > 0.05) was found out in average egg weight in treatments. In the present experi-

Table 4. Effects of Jerusalem artichoke on egg weight and shell quality

Treatment groups	Egg weight[1] (g) $\bar{x}$ $S_{\bar{x}}$	Egg breaking strength[2] (kg/cm^2) $\bar{x}$ $S_{\bar{x}}$	Shell weight[2] (g) $\bar{x}$ $S_{\bar{x}}$	Shell thickness[2] (mm × 10^{-2}) $\bar{x}$ $S_{\bar{x}}$
Control	60.33^{ab} ± 0.34	2.93^{ab} ± 0.08	5.11^{ab} ± 0.09	36.03^{ab} ± 0.24
5% V	60.60^{ab} ± 0.32	2.99^{ab} ± 0.09	5.35^{a} ± 0.09	36.52^{a} ± 0.19
5% JA	61.20^{a} ± 0.34	2.94^{ab} ± 0.13	5.13^{ab} ± 0.13	36.58^{a} ± 0.23
5% JA + 5% V	60.80^{a} ± 0.73	2.81^{b} ± 0.19	4.63^{b} ± 0.18	34.65^{b} ± 0.67
10% JA + 10% V	58.67^{b} ± 0.27	3.26^{a} ± 0.09	5.26^{a} ± 0.10	36.57^{a} ± 0.20
F-value	5.93***	1.99*	5.14***	6.03***

^{a,b}means with different superscripts differ significantly (P < 0.05, P < 0.001)

[1] means for a 16-week period

[2] means for four 4-week periods

Table 5. Effects of Jerusalem artichoke on interior egg quality

Treatment groups	Yolk index		Albumen index		Haugh unit		Yolk colour	
	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$
Control	44.02^{a}	± 0.34	10.03^{a}	± 0.23	87.23^{a}	± 0.78	5.23^{b}	± 0.20
5% V	42.97^{ab}	± 0.28	9.59^{ab}	± 0.21	86.03^{ab}	± 0.84	5.14^{b}	± 0.17
5% JA	42.75^{b}	± 0.33	8.74^{b}	± 0.17	83.12^{b}	± 0.79	5.04^{b}	± 0.20
5% JA + 5% V	42.86^{b}	± 0.32	9.59^{ab}	± 0.39	84.00^{b}	± 1.98	6.00^{a}	± 0.23
10% JA + 10% V	43.37^{b}	± 0.28	9.25^{ab}	± 0.23	84.04^{b}	± 1.00	5.43^{ab}	± 0.17
F-value	2.88**		3.98***		2.69*		3.28**	

^{a,b}means with different superscripts differ significantly (*P < 0.05, **P < 0.01, ***P < 0.001)
means for four 6-week periods

Table 6. Effects of Jerusalem artichoke on cholesterol content

Treatment groups	Yolk cholesterol (mg/g yolk) $\bar{x}$ $S_{\bar{x}}$	Total cholesterol (mg/egg) $\bar{x}$ $S_{\bar{x}}$
Control	11.01 ± 1.07	196.17 ± 18.99
5% V	10.39 ± 0.91	181.60 ± 16.24
5% JA	10.17 ± 1.00	180.92 ± 18.56
5% JA + 5% V	12.89 ± 0.93	231.74 ± 19.08
10% JA + 10% V	11.83 ± 0.84	204.18 ± 17.15
F-value	1.32^{-}	1.28^{-}

ment shell breaking strength (kg/cm^2) (P < 0.05), eggshell weight and eggshell thickness were significantly (P < 0.001) decreased in the treatment group 5% JA + 5% V compared with the other groups (Table 4). Chen and Chen (2004) reported that oligofructose and inulin did not affect the eggshell weight percentage during the first week of feeding. On the other hand, after 1 week of feeding, both prebiotics increased eggshell weight and also eggshell strength compared with the controls.

Interior egg quality characteristics and cholesterol content are given in Table 5 and Table 6, respectively. Haugh units were lower (P < 0.05) in the treatment groups compared to the control (Table 5). Indeed Chen et al. (2005) reported that Haugh units of shell eggs were not (P > 0.05) affected by oligofructose or inulin treatment. Albumen index (P < 0.001) and yolk index (P < 0.01) were lower in the treatment group 5% JA than in the control group. It was observed that egg yolk colour in treatment group 3 was similar like in the treatment groups 10% JA + 10% V while higher (P < 0.01) than in the other groups.

Egg yolk cholesterol contents of the control and treatment groups 5% V, 5% JA, 5% JA + 5% V, 10% JA + 10% V were found to be 11.01, 10.39, 10.17, 12.89 and 11.83 mg/g yolk (Table 6). No statistically differences were observed between the groups. Turk and Barnet (1973) reported that egg yolk cholesterol content was decreased by the addition of 2% pectin being a prebiotic like inulin. Similarly, in the studies conducted by Rotenburg and Mason (1977) and Stadermann (1989), egg yolk cholesterol contents were determined to amount to 14.8, 14.0 and 13.8 mg/g yolk and 10.8, 13.14 and 12.6 mg/g yolk in the groups added 2, 4 and 6% pectin, respectively.

CONCLUSION

It was concluded that the supplementation of Jerusalem artichoke as an inulin source with or without vetch had no adverse effect on laying hen performance and interior and exterior egg quality or egg cholesterol level. Finally, the effect of JA or other fruits and vegetables containing inulin on the performance and health in animals should be determined. The possible substitution of antibiotics with fructans in animal diets should also be presented.

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Received: 2005–10–06
Accepted after corrections: 2006–03–28

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