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DIETARY LINSEED INCLUSION AND EARLY-AGE ACCLIMATION EFFECTS ON CARCASS YIELD, ORGANS DEVELOPMENT AND THERMAL RESISTANCE OF BROILERS IN HOT CLIMATE

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Abstract

Poultry and particularly commercial broilers performance is known to be highly sensitive to temperature–associated environmental challenges. Dietary ground linseed (GLS) inclusion and early age thermal conditioning (EATC) effects on the correlation of carcass yield and weight development of some organs at three different ages were studied. One-day old broiler chicks (n=400) were randomly allocated into 2 equal groups (n=200). At 5 days-old, one of the groups (AC) was exposed to 39±1°C for 24 hours, while the other was control (C). At 17 d-old, both groups were subsequently divided into two equal subgroups: C and AC groups were fed basal diet, where CL and ACL birds were fed 5% GLS (*Linum usitatissimum*) supplemented diet till marketing age of 54 days. Both fed diets had isocaloric metabolizable energy. Groups of birds were slaughtered at 30 d-old (A1), 43 d-old (A2) and 53d-old (A3). Results showed that as a whole, acclimated birds displayed higher yields of the scalded, eviscerated and skinned carcass at A1, while that of the eviscerated carcass at A2 was decreased in EATC birds. Leg content was significantly augmented in birds fed GLS at A2. Dietary GLS supplementation led to a decrease of the gizzard at A1 and A3, while EATC diminished the percentage of heart at A2, and intestine at A1 and A2. Both factors acted in dependence of the age on the valuable carcass cuts where considerable increase in breast percentage at A3 compared to A2 was noticed. In conclusion, combination of both factors (early-age acclimation and dietary 5% linseed supplementation) affects carcass yield in a positive way and seems, in hot countries, to be a better strategy to improve animal's performance, nutritional quality and economic development. Therefore, it could be recommended to farmers to use this combination for better performance and improved thermoresistance in hot climate or during heat stress.

Key words: broilers, carcass yield, early-age acclimation, hot climate, linseed

List of abbreviations:
AC**:** acclimated
ACL: acclimated fed Linseed
EATC: Early-Age Thermal Conditioning
GLS: Ground Linseed
PUFA: Polyunsaturated Fatty Acids

Introduction

Poultry industry has been playing a major role in the agricultural sector in many parts of the world and a remarkable growth in the production of the primary poultry products-meat and eggs exists. The latter are high quality foods and serve as an important source of protein in healthy and bal-

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anced human diet throughout the world (Anders and Jorgen, 1998). Beside the globally increasing consumption of poultry products, its levels still remain relatively low in hot climate regions, thus revealing their high potential for further growth of the poultry sector (Daghir, 2008). Development of poultry production in hot countries meets several constraints, the most obvious of which is climate. Poultry and particularly commercial broilers are known to be highly sensitive to temperature–associated environmental challenges (Bhadauria et al., 2014), high ambient temperatures when coupled with increased humidity impose severe stress on birds. Since the optimal temperature for the finishing period is from 20°C to 25°C (Yahav, 1998), any increase in the ambient temperature over 25°C reduces growth rate up to 25% (Yahav and Hurwitz, 1996). It was also reported that the highest growth rate of broilers is obtained in ambient temperatures ranging from 10 to 22° C (Kampen, 1984) and the optimum performance occurs in the range of 18 – 22° C (Charles, 2002). Therefore, high ambient temperatures cause significant economic losses to farmers and subsequently considerable price rising to consumers. In addition to the high mortality rates, heat stress interferes with the broilers welfare, suppresses the productive performance, growth rate, feed efficiency and weight gain and negatively affects the carcass quality (Etches et al., 1995; Yalcin et al., 1997). Losses caused by heat can be limited by practices, enhancing the adaptability of broilers to heat stress conditions, such as early age thermal conditioning (EATC) (Yahav and Hurwiz, 1996). It has been proved to be an effective way to increase thermo resistance in chickens, leading to greater adaptability to high temperatures in the final rearing period (Tan et al., 2010) and hence reducing the detrimental impact of the hot climate on broilers growth and performance. However, EATC of broilers at 39±1°C for 24 h during the 5th day of age enables, at marketing age, to lute against decreased final body weights caused by elevated chronic ambient temperatures (Etches et al., 1995; Yalcin et al., 1997; Bengharbi et al., 2014). As stated above, the ambient temperature is the most important factor affecting the feed intake and weight gain of broilers. Several authors have shown that increasing the energy content of the diet can partially overcome this growth depression, especially by adding fat. Ghazalah et al. (2008) showed that high fat diets (5%) helped in reducing the detrimental effect of heat stress in broilers raised in high temperatures due to the reduced heat production, since fat has a lower heat increment than either proteins or carbohydrates. Mateos and Sell (1981) found that dietary fat addition also appears to increase the energy value of other feed constituents and has been shown to decrease the rate of food passage in the gastrointestinal tract and thus increases nutrient utilization (Mateos et al., 1982).

Linseed is an important source of fat in diets for animals and poultry as it contains 35-45% oil of which, more than 70% alpha-linolenic fatty acids (Martinchik et al., 2012). It has been preferred for the high contents of linolenic acid that is a precursor for the synthesis of the other beneficial n-3 PUFA (poly unsaturated fatty acids). It has been shown that in poultry the high dietary PUFA can affect the carcass composition by reduction of body fat (Newman et al., 2002; Ferrini et al., 2008; Wongsuthavas et al., 2008). However, research on the possible effect of PUFA on other carcass parts is scarce.

The aim of this work is to investigate the effect of an early age (5^{th} day) thermal conditioning (EATC) and 5 % dietary ground linseed (GLS) supplementation and their combination at three different ages on carcass composition and organ weights of broilers raised in high ambient temperature.

Material and Methods

Experimental design

A total of 400 one-day chicks of a commercial breed (ISA Hubbard) were randomly divided into 2 groups (200 birds each). At 5 days of age one group (Acclimated: Ac) was exposed to 39±1°C for 24 hours (early age thermal conditioning), the second was the control group (C). At the end of the starter phase (17 days) both groups (C and AC) were subsequently divided into two subgroups: C and AC groups fed basal diet while CL and ACL birds were fed 5% ground linseed (*Linum usitatissimum*) supplemented diet. Both fed diets were isocaloric metabolizable energy (ME: 2887.06 Kcal/kg). Feedstuff and levels of metabolizable energy of starter, grower and linseed were calculated (Carpenter and Clegg, 2006). All experimental birds were reared (according to the European legislation for the protection of animals used for scientific purposes) in an ambient temperature of 21±1°C at Mostaganem University poultry station.

Slaughtering and measurements

At 30 (A1), 43 (A2) and 53 (A3) days-old, twenty birds from each group were randomly selected, weighed and then slaughtered. Afterwards, animals were scalded, eviscerated and skinned and their weights were recorded. Breast, thigh and abdominal fat, as well as the internal organs heart, liver, proventriculus, gizzard and intestine were carefully excised and separated from each carcass and weighed respectively. Carcass weights, separated parts and the internal organs were calculated as follows: in order to estimate the economical values, weights of scalded, eviscerated and skinned carcasses were expressed as percentage of the live weight of the bird and, to evaluate the usual nutritional edible portions and fat depot, breast, thigh, skin and abdominal fat were expressed as proportion of the eviscerated carcass. Moreover, to investigate the physiological influence of the two treatments on internal organs: heart, liver, proventriculum, gizzard and intestine were expressed as a proportion of the live weight, and the weight of breast and thigh was also calculated as percentage of the skinned carcass.

Statistical analysis

Data were analyzed by two-way analysis of variance by the ANOVA procedure. The model included the main effects of the early age thermal conditioning (EATC), 5% dietary linseed supplementation (GLS) and their interaction. The statistical evaluation was done by JMP v. 7 software package.

Results and Discussion

The early age thermal conditioning of broilers at A1 (Table 1) augmented the weight of the scalded birds, calculated as percentage of the live weight, however it was visible only in the group fed linseed, and was confirmed by the significant interaction with linseed supplementation (P<0.001) observed for this trait. Both factors significantly interacted in regards to the weight of the scalded birds slaughtered at A2 (P<0.01) and A3 (P<0.001). However for the latter, linseed diminished the birds' weight where the effect was more pronounced in the acclimated birds.

The thermal conditioning increased the weight in the eviscerated (P<0.001) broilers at A1 while at A2 it significantly decreased the weight of birds. At A1 linseed only affected the weight of the eviscerated birds (P<0.01), but its influence was limited to the group that was not acclimated. The control birds receiving linseed in the diet exhibited lower weight of the eviscerated carcass than the ones without supplementation. In the groups slaughtered at the age of 53 d-old, significant interaction between acclimation and linseed was detected (P<0.01), with contradictory trends in the groups, showing lower values in the control birds receiving linseed, while higher weight in the acclimated broilers after linseed supplementation.

The weight of the skinned birds at A1 was significantly increased by EATC (P<0.05). At A2, the factor interacted significantly with the linseed supplementation (P<0.05), while at A3, no significant effect of either acclimation or linseed was observed.

In regards to the percentage of the various parts of the carcass (Table 2) in the birds slaughtered at age 1 (A1), linseed supplementation had a more pronounced influence than the thermal conditioning.

The skin of birds receiving linseed had higher percentage (P<0.001) while the opposite was observed for the legs in response to the linseed supplementation. Significant interaction between thermal conditioning and linseed supplementation was found in breast (P<0.01) and abdominal tissue (P<0.001). The latter had higher content in the groups fed linseed, more pronounced in the thermally condition chickens. At A2, thermal acclimation of broilers increased the percentage of skin and breast of the eviscerated carcass (P<0.001). The latter

Table 1
Effect of EATC and GLS on weights of scalded, eviscerated and skinned carcasses as percentage of the live weight of broilers

Age, days	Weight %	Experimental groups				RMSE	Significance		
		C	CL	AC	ACL		EATC	5% GLS	EATC x GLS
A1, 30	Scalded	82.77	84.09	86.2	84.08	1.44	***		***
	Eviscerated	65.52	68.95	71.89	71.28	2.08	***	**	
	Skinned	56.06	58.88	60.64	59.79	5.19	*		
A2, 43	Scalded	83.93	80.39	74.21	83.82	11.22			**
	Eviscerated	77.64	76.15	69.48	71.87	6.88	***		
	Skinned	56.56	67.16	67.16	59.46	6.73	**	***	*
A3, 53	Scalded	80.51	80.07	87.76	77.37	4.29		***	***
	Eviscerated	67.33	70.07	74.92	64.60	8.73			**
	Skinned	60.72	58.86	60.45	62.79	5.94			

EATC: Early-age thermal conditioning; GLS: Ground linseed; C: control birds; CL: Control fed Linseed;
AC: early-age Acclimated; ACL: Acclimated and fed Linseed.
* p<0.05; ** p<0.01; *** p<0.001.

Table 2
Effect of EATC and GLS on weights of skin, breast, leg and abdominal fat as percentage of the eviscerated carcass of broilers

Age, days	Weight %	Experimental treatments				RMSE	Significance		
		C	CL	AC	ACL		EATC	5%GLS	EATC xGLS
A1, 30	Skin	11.24	12.72	11.06	12.65	1.15		***	
	Breast	7.91	8.84	8.96	8.57	0.87			**
	Leg	14.57	13.02	14.44	13.15	0.88		***	
	Abdominal fat	1.38	1.71	0.83	1.76	0.32	**	***	***
A2, 43	Skin	12.90	13.84	11.31	10.94	1.24	***		*
	Breast	9.72	9.63	9.51	7.25	1.27	***	***	***
	Leg	12.53	13.94	13.61	13.91	1.58		*	
	Abdominal fat	1.79	2.22	2.05	2.01	0.45			*
A3, 53	Skin	10.49	11.25	10.52	10.39	1.42			
	Breast	7.72	9.69	8.49	10.01	0.56	***	***	
	Leg	15.06	14.62	13.84	15.31	1.56			**
	Abdominal fat	1.66	1.73	2.27	1.79	0.57	***		***

EATC: Early-age thermal conditioning; GLS: Ground linseed; C: control birds; CL: Control fed Linseed; AC: early-age Acclimated; ACL: Acclimated and fed Linseed.
* p<0.05; ** p<0.01; *** p<0.001.

was decreased in response of the linseed supplementation of the diet (P<0.001) more pronounced in the acclimated group. For both parts significant interaction between both factors existed (P<0.001). Again the thermal conditioning and linseed in the diet interacted significantly in regards to the percentage of the abdominal fat in the birds at this age while the leg displayed significantly increased content (%) in response to the linseed supplementation (P<0.05).

Both factors significantly affected the percentage of the breast (P<0.001) in the birds slaughtered at age A3. Early age thermally conditioned birds had higher values of the trait while linseed diminished the part of the breast in both groups. Acclimation and linseed supplementation interacted significantly (P<0.001) in regards to the percentage of leg and abdominal fat. Nonetheless, the latter was significantly higher in the acclimated groups (P<0.001).

Interaction between the acclimation and linseed was detected in the percentage of the internal organs – liver and gizzard (P<0.001) in the birds at age A1 (Table 3). In these two organs contradictory trends were observed, more clearly in the gizzard where reduction of the weight was observed in the acclimated group. Thermal conditioning led to significant decrease (P<0.001) in the weight of the intestine, while no effect of it or linseed supplementation was found in heart and proventriculus.

The early age thermal conditioning led to significant decrease in the percentage of the heart, proventriculus and intestine in birds at A2 (P<0.001). The intestine was affected by the linseed supplementation, leading to higher content of this organ in both control and acclimated birds (P<0.001). Significant interaction between acclimation and linseed was observed in gizzard (P<0.001).

The acclimated slaughtered birds at age 3 exhibited higher percentage of liver (P<0.001), although significant interaction with linseed existed between this factor and linseed in the diet (P<0.05). Linseed affected the content of the gizzard and intestine in an opposite way (P<0.001) showing decreased percentage of the gizzard while increasing that of the intestine. However, significant interaction between thermal conditioning and linseed was determined for the intestine content (P<0.05). Such interaction (P<0.001) was observed in regards to the percentage of the proventriculus in this age's birds group.

Significant interaction between early age thermal conditioning and linseed was observed in regards to the percentage of the breast in the skinless chickens at the age 1, 2 and 3 (P<0.001) (Table 4). On the other hand, the percentage of the leg was significantly decreased by the linseed supplementation (P<0.001) in birds at age 1, while at age 2 both factors interacted significantly (P<0.01).

Table 3
Effect of EATC and GLS on weights of heart, liver, proventriculus, gizzard and intestine as percentage of the live weight of broilers

Age, days	Weight %	Experimental treatments				RMSE	Significance		
		C	CL	AC	ACL		EATC	5%GLS	EATC x GLS
A1, 30	Heart	0.5	0.51	0.49	0.54	0.1		**	***
	Liver	2.66	2.93	3.14	2.26	0.45			
	Proventriculus	0.41	0.4	0.42	0.43	0.09			
	Gizzard	3.55	3.25	3.41	2.7	0.38	**	***	***
	Intestine	6.74	6.49	5.21	5.27	0.92	***		
A2, 43	Heart	0.48	0.52	0.43	0.42	0.05	***		
	Liver	2.29	2.13	2.13	2.13	0.25			
	Proventriculus	0.39	0.40	0.32	0.35	0.08	***		
	Gizzard	2.71	1.89	2.18	2.47	0.47		*	***
	Intestine	5.07	5.89	4.53	5.12	0.53	***	***	
A3, 53	Heart	0.47	0.46	0.47	0.45	0.09			
	Liver	2.33	2.27	2.41	2.88	0.49	**		*
	Proventriculus	0.42	0.32	0.38	0.39	0.05		***	***
	Gizzard	2.78	2.36	2.62	2.09	0.52		***	
	Intestine	5.43	5.74	5.02	6.08	0.70		***	*

EATC: Early-age thermal conditioning; GLS: Ground linseed; C: control birds; CL: Control fed Linseed;
AC: early-age Acclimated; ACL: Acclimated and fed Linseed.
* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Table 4
Effect of EATC and GLS on breast and leg as percentage of the skinned carcass weight of broilers

Age, days	Weight %	Experimental treatments				RMSE	Significance		
		C	CL	AC	ACL		EATC	5% GLS	EATC x GLS
A1, 30	Breast	8.92	10.24	10.2	10.17	1.01	**	***	**
	Leg	16.55	15.51	16.94	15.6	0.99		***	
A2, 43	Breast	10.00	13.90	12.14	8.77	1.81	***		***
	Leg	16.19	18.06	17.36	16.81	2.04			*
A3, 53	Breast	8.53	11.21	10.59	10.90	1.05	***	***	***
	Leg	16.53	17.41	17.40	16.90	2.01			

EATC: Early-age thermal conditioning; GLS: Ground linseed; C: control birds; CL: Control fed Linseed;
AC: early-age Acclimated; ACL: Acclimated and fed Linseed.
* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Currently, methods aiming to improve the thermo tolerance in chickens are gaining much interest. The thermal conditioning at the early age of the chicks when the mechanisms regulating the body temperature are immature improves thermo tolerance (Yahav, 2000) but has an impact on the broilers productive traits. Our results show increase in the weight (%) of the scalded, eviscerated and skinned carcasses due to the early age thermal conditioning in the birds slaughtered at the age of 30 days (A1). Contrary to our results, Fernandes et al. (2013) did not find significant influence of the thermal conditioning of broilers on the carcass yield at 42 days of age, while Oliveira et al. (2006) reported increased carcass yield in chickens reared in ambient temperatures ranging 16, 20, 25 and 32°C from 22 days to 42 days old. Linseed dietary inclusion affected significantly the percentage of the eviscerated carcass of A1 birds, showing increased value in the control, not acclimated group. Such a tendency was observed in the scalded and skinned birds as well. This corresponded with the significantly increased content of skin, liver and abdominal fat in this group in response to the dietary linseed supplementation. Contrary to our results, feeding linseed in the diet of poultry did not affect the carcass yields (Lee et al., 1991) and even led to smaller carcass size (Ajuyah et al., 1991). However, at older age (A2 and A3), the linseed in the diet interacted significantly with the thermal conditioning, suggesting possible modification of the linseed action by the acclimation and also on the dependence of the examined factors on birds' age.

In regards to the proportion of the carcass parts, the early age thermal conditioning and linseed supplementation of the diet had different effect on the different ages of birds. At 30 days old birds, linseed augmented the percentage of the skin and abdominal fat, while reducing that of the leg. The percentage of the latter was however augmented in the birds slaughtered at A2. At the age of 43 days (A2) and 53 days (A3) linseed displayed opposite effect on the breast proportion. The birds slaughtered at A2 had lower breast percentage in response to linseed in the diet. The effect was more pronounced in the acclimated group and confirmed by the significant interaction between the two factors. On the other hand the groups at A3 had higher content of the breast when receiving linseed. The result corresponded to that of the percentage of this carcass part in the skinned carcass (Table 4). The separation of the whole broiler carcass into cut-up parts and further processed products has made poultry an important meat source in many households. Therefore the significant (breast and leg) and insignificant responses elicited by the experimental conditions of this study (acclimation and linseed supplementation) might be of practical and economic significance to broiler producers, as a result of the differences in retail value for broiler portions.

Our results coincide partially with those reported by Ajuyah et al. (1991). The authors reported lower breast and higher leg proportion in poultry at 42 days of age. On the other hand Almeida et al. (2009) and Duarte et al. (2013) found no influence of the inclusion of dietary linseed oil in broilers on the yield of breast and leg at 42 days old birds. The authors reported also increased content of abdominal fat at the age of 56 days in broilers, which coincides in part with our results, since at the age of 43 and 53 days in our study the linseed augmented the abdominal fat in the group that was not subjected to thermal conditioning. This was additionally confirmed by the significant interaction between linseed and acclimation observed in all the age groups. Crespo and Esteve-Garcia (2001) as well as Murakami et al. (2010) observed reduced deposition of abdominal fat when feeding broilers with linseed oil and soybean oil respectively. However in a previous article (Bengharbi et al., in press) we found decreased lipid content in the abdominal fat which might confirm the results of these authors that the fat deposition could be modified through inclusion of PUFA in the diet. Although interacting with the dietary linseed supplementation, thermal conditioning decreased the percentage of skin and breast in the broilers at A2, while at the third age A3 it increased the content of breast as well the abdominal fat percentage. Fernandez et al. (2013) found no effect of the early age thermal conditioning on the separated carcass parts, while De Basilio et al. (2001), described increased breast weight mass in birds at 41 days of age submitted to thermal conditioning at 38ºC until 5 days old.

In regards to the percentage of the internal organs again the acclimation and linseed supplementation displayed different effect on birds' age. In the broilers at the age of 30 days, the linseed reduced the percentage of gizzard in both group, while augmenting the content of liver in the control group without acclimation. At age 43 days, the gizzard was reduced in the control birds receiving linseed, while the content of intestine was augmented in both groups in response to the linseed. These changes were observed in the birds at A3. The early age thermal conditioning decreased the intestine percentage in the birds slaughtered at A1 and A2, as well as that of heart and proventriculus at A2. At A3 the liver content was increased due to thermal conditioning. Fernandes et al. (2013) found reduced heart area in birds subjected to a thermal conditioning at 35 days of age. On the other hand De Basilio et al. (2001) reported significant augmentation in the weight of liver and gizzard in the early age conditioned birds. Our results suggest that thermal conditioning together with linseed supplementation of the diet induce significant changes in the metabolism of the broilers at different age.

Conclusion

The study show that early age thermal conditioning and dietary linseed supplementation, in addition to the known meat quality and the thermo resistance improvements, affect the carcass yield, percentage of the carcass parts and internal organs weights in broilers slaughtered at different age. It highlights the combined effects of the two treatments at different age on the proportional weights of the usual edible different parts of the bird to the non-edible ones. The significant interactions between factors often observed in the study do not allow us to draw firm conclusions on the effect of acclimation and linseed in the diet on the carcass characteristics in broilers. Further studies are necessary in order to clarify the dependence between the factors toward modifying the carcass qualities in broilers in a positive way.

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