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Full Length Research Paper

Effects of early and chronic exposure to high temperatures on growth performance, carcass parameters and fatty acids of subcutaneous lipid of broilers

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This study was conducted to assess the effects of early and chronic exposure of broilers at a scorching temperature on growth performance, carcass parameters, fatty acid deposition and composition of subcutaneous lipids (SCL). Three hundred male chicks (Hubbard origin) of a day are reared for 50 days. They are divided into three groups, each of cent chicks. The chronic thermal environments are applied from the 8th growing day: a neutral temperature (NT: 25 ± 2°C) for the first one, a moderate summer temperature (MT: 32 ± 2°C) for the second and hot temperature (HT: 37 ± 2°C) for the third. The results were summarized as follows: (1) from the 40th day, a decrease of 37 g/d of feed intake (FI) related to HT was observed; (2) a higher body weight (BW) of NT chickens was recorded from the 40th day; (3) regarding the early breeding, a higher daily weight gain (DWG) was recorded in HT chickens at the end of rearing; (4) compared to other temperature, the feed conversion ratio (FCR) of HT chickens was significantly better from 40th day; (5) at the end of breeding, the yields EC/BW: eviscerated carcass weight (EC) on body weight (BW) were comparable as recorded in NT and HT chickens; (6) at the end of breeding, a decreased weight of pectoral muscle (PM) associated with the HT was observed: -17 and -20% compared with TM and TN, respectively; (7) a higher deposit of SCL up to 105g/Chicken and SCL/EC (+7.3% compared with NT) occur in the HT chickens mainly at the end of rearing; (8) conversely, the abdominal fat weight (AF) was higher in NT chickens from the 32th day; (9) compared with NT chickens, an increase in the proportion of saturated fatty acids (SFA) and polyunsaturated (PUFA) of SCL was obtained in HT chickens of 50 days. No temperature effect on the monounsaturated fatty acids proportion (MUFA) of LSC has been highlighted. Finally, the HT resulted in a significant decrease of the UFA/SFA ratio reflecting a degree of SCL saturation greater in HT chicken carcass; (10) these results have shown that chickens can tolerate early and chronic higher temperatures.

Keys words: Temperature, broilers, growth, subcutaneous lipids, fatty acids.

INTRODUCTION

Algeria is among the first producers of poultry meat in Africa with an estimated production of over 25 10^4 tons in 2008 and a consumption of about 6.7 Kg/head/year (OECD-FAO, 2009 to 2018). However, it is a country which has an insufficient poultry equipment industry to cope with various problems that may affect a modern poultry such as weather conditions. Among these, the often very high and persistent summer temperatures are a major obstacle to a successful poultry farm in Algeria. In many countries, they cause considerable losses in terms of mortality (De Basilio et al., 2001c) or declines in breeding performance (Settar et al., 1999; Veldkamp et al., 2000; De Basilio et al, 2001a, b; Mashaly et al., 2004).

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Table 2. Feed intake, body weight, daily weight gain and feed conversion ratio of chickens exposed to the scorching summer temperatures (TC), moderate summer temperature (TM) and neutral temperature (TN).

Age (day)		14	28	40	50
FI (g/day)	NT	43.14	93	120	154
	MT	39.28	87.43	125	140
	HT	42.86	92	111	117
BW (g)	NT	298±39^{i}	838±103^{f}	1642±106^{d}	2092±110^{a}
	MT	344±30^{h}	793±67^{g}	1440±143^{e}	1993±123^{b}
	HT	343±19^{h}	802±85^{f}	1453±148^{e}	1907±129^{c}
DWG (g/day)	NT	28.8±2.7^{e}	42.4±12.2^{c}	68.1±17.4^{a}	69.1±14.5^{a}
	MT	27.8±3.8^{e}	41.8±9.2^{c}	53.7±15.1^{b}	57.7±15.4^{b}
	HT	22.2±5.8^{f}	39.5±10.6^{cd}	42.4±12.7^{c}	53.3±11.8^{b}
FCR	NT	1.46±0.09^{h}	2.06±0.25^{cd}	2.26±0.23^{a}	2.20±0.15^{ab}
	MT	1.36±0.13^{hi}	1.94±0.18^{def}	2.21±0.25^{ab}	2.09±0.15^{bc}
	HT	1.78±0.26^{g}	1.98±0.23^{cde}	1.86±0.13^{efg}	1.87±0.09^{efg}

Each result represents the mean value followed by standard deviation (SD); n = 32. Mean values with different superscript letters were significantly different ($P < 0.05$). FI, Feed intake; BW, body weight; DWG, daily weight gain; FCR, feed conversion ratio.

In USA and Brazil, losses were estimated at one million chickens per month during the warm periods (Brown, 1986; Gabriel et al., 1996). In Morocco, an Algeria frontier country, nearly five million birds died during the heat wave of 2003, causing an economic loss of about 11.83 millions USD. In Algeria, to face this phenomenon, many farmers prefer to avoid the breeding of broilers in summer (Alloui and Tlidjene, 2001).

To deal with this constraint, many studies on bird's acclimatization to high temperatures were generally undertaken on a short or medium duration of exposure (Beaumont et al., 1998; Yalcin et al., 2001a, b; De Basilio et al., 2001a, b). In general, the duration of animal exposure must be shorter as the temperature is higher (De Basilio et al., 2001a). In contrast, for chronic exposure to heat, the tested temperatures were moderately high between 30 and 32°C (Ain Baziz, 1996; Cooper and Washbum, 1998; Temin et al., 2000a, b). These temperatures are often associated with lower weight and food intake resulting in a less efficient conversion index (CI) in chickens at the end of rearing. They also produce a more pronounced fat (Geraert et al., 1996; Cahaner and Leenstra, 1992; Ain Baziz et al., 1996; Al-Fataftah and Abu-Dieyeh, 2007). The same trends were observed in chickens exposed for short periods at temperatures around 35 to 36°C (Ozbey and Ozcelik, 2004).

In this context, we propose to test other more severe thermal environment conditions. Thus, the objectives of this study were to determine the effects of early and chronic exposure to scorching temperatures (37 ± 2°C) on growth performance, carcass parameters and fatty acid composition of SCL of chickens.

MATERIALS AND METHODS

Animals and diets

Three hundred (300) male chicks of one day (Hubbard origin) were reared for 50 days. The chicks were divided into three (3) groups of cent each. Chronic different thermal environments had been applied from the 8th day of rearing, an optimum temperature or neutral temperature (TN: 25 ± 2°C) for the first group, a moderate summer temperatures (MT: 32±2°C) for the second and scorching summer temperatures (HT: 37 ± 2°C) for the third. The average weight of day chicks was 37.1 ± 3.2 g. The animals received *ad libitum* daily food and drinking water. The characteristics of the distributed food are presented in Table 1. The measurements of body weights (BW), feed intake (FI), feed conversion ratio (FCR) and daily weight gains (DWG) were performed at the age of 14, 28, 40 and 50 days. The chickens were slaughtered at age 25, 32, 40 and 50 days. The carcasses were eviscerated and cut by hand to determine the weight of eviscerated carcass (EC), the weight of subcutaneous lipids (SCL) of whole carcass, the abdominal fat (AF) and the pectoral muscle (PM) weight. Samples of subcutaneous adipose tissue were made and stored at -20°C for analysis.

Laboratory analysis

The proteins of diets were measured by the Kjeldahl method (AOAC, 1995). The concentration of crude fiber diets was determined by the Weender method after double hydrolysis of non-cellulose components respectively in an acid solution and basic one (AOAC, 1995). The lipids content of feeds was determined by extraction in Soxhlet apparatus by petroleum ether (AOAC, 1995). The SCL of animals were extracted and determined by the chloroform-methanol (2v: 1v) mixing using the method of Folch et al. (1957). The fatty acid composition of SCL was determined after extraction by the method of Folch et al. (1957), by saponification using sodium hydroxide and methylation (Morisson and Smith, 1964) and gas chromatograph analysis (Perkin-Elmer Auto System XL) with a capillary column (30 m per 0.25 mm internal diameter).

Statistical analysis

The statistical analysis were carried out by Win stat software using a variance analysis with two factors (temperature and age) followed by a comparison of means.

Table 2: Composition and nutritional characteristics of foods

Aliments	Starting	Growth
	g/kg of aliment	
Corn	650	670
Soya bean	280	260
Bran	40	40
Calcium carbonate	10	10
Phosphate	10	10
CMV [1]	10	10
L-Methionine	0.3	-
	Composition (% of food)	
EM (kcal/kg food) [2]	2950	2990
Proteins	20	19
Lipids	3.56	3.49
Crude fiber	2.77	2.80
Mineral materials	4.30	4.16
Moisture	5.5	6

[1] Mineral Vitamin Premix (mg per kg food): Iron: 60; Copper: 10; Zinc: 80; Manganese: 80; Cobalt 0.2, Selenium: 0.2; Iodine: 1; Vitamin E: 15; Menadione (K3): 5; Thiamin (B_1): 3, Riboflavin (B_2): 7; Pantothenic acid (B_5): 10; Niacin: 30, Folic acid (B_9): 0.5; Vitamin B12: 0.02: Pyridoxine (B_6): 4, Choline chloride: 300
[2] Metabolizable Energy

RESULTS

Growth performance

The results of growth performance of broilers in relation to rearing temperatures and ages are listed in Table 2. For NT, a gradual increase in FI with age was observed, reaching a total of 111 g/day between the 14th and 50th day. In contrast for the HT, the FI increase was significant up to 28th day and it becomes less pronounced after the 40th day. It is only 74 g/jour between the 14th and 50th day. Between NT and HT, insignificant FI differences of about 1 g/day were observed up to day 28. From the 40th day, FI decreases related to HT and reach 37 g/day.

Up to the age of 40 days, similar body weights (BW) of MT and HT chickens were observed. However, a significant decrease ($P < 0.05$) (-4.3%) of BW of HT chickens was recorded at the end of rearing compared with MT chickens. This decrease of BW was more pronounced in chickens exposed to HT compared to those of NT (-8.8%). Finally, the significant superiority ($P < 0.05$) of the NT chickens was observed only from the 40th day.

From the first week of thermal exposure, the daily weight gain (DWG) was significantly ($P < 0.05$) lower in the HT chickens. Until the 28th day, no DWG difference was observed between the NT and MT chickens. From the 40th day, a significant DWG increase ($P < 0.05$) was recorded in NT animals. Finally, a significant DWG increase ($P < 0.05$) was noted in HT chickens at the end of rearing. The feed conversion ratio (FCR) increased significantly until the 40th day, from 1.46 to 2.26 for NT and 1.36 to 2.21 for MT and then FCR increases significantly ($P < 0.05$) at the end of breeding for both NT and MT. For HT, the small amounts of FI had resulted in low FCR at the end of rearing. In fact, compared with other temperatures, the FCR of HT chickens were significantly better ($P < 0.05$) from the 40th day.

Carcass parameters

The results of carcasses parameters according to the tested temperatures are summarized in Table 3. It appears that scorching temperature affects negatively the weight of eviscerated carcass (EC). Indeed, at the rearing end, a significant difference ($p < 0.05$) of about 189 g was recorded between the HT and NT chickens. The same trend was noted between the EC weight of HT and MT chickens. Finally, we noted a significant and progressive increase in EC weight as a function of age for all temperatures,

At the end of rearing, the obtained carcass yields (EC/BW) were comparable in chickens exposed to NT and HT. In contrast and compared with NT and HT temperatures, an EC/BW significantly lower ($p < 0.05$) was obtained after breeding in MT chickens (-71%).

Regardless the tested temperatures of rearing, a significant increase ($p < 0.05$) EC/BW with age was noted.

Until the 25th day, the MT and HT seem favorable for

Table 3. Evolution of the carcass parameters to scorching summer temperatures and moderate (TC and TM) and neutral temperature (TN).

Parameter	Age (day)	Breeding temperature		
		NT	MT	HT
EC(g) (n=10)	25	463±26^{i}	405±21^{j}	394±6^{j}
	32	653±25^{h}	712±58^{g}	671±29^{h}
	40	1142±27^{d}	1030±18^{f}	1066±19^{e}
	50	1552±33^{a}	1418±13^{b}	1363±25^{c}
EC/BW(%) (n=10)	25	49±2^{g}	51±3^{fg}	56±2de
	32	59±4^{d}	66±7^{c}	57±3de
	40	72±3^{ab}	71±5^{ab}	69±2^{b}
	50	75±3^{a}	71±3^{ab}	74±1^{a}
PM (g) (n=8)	25	64±08^{g}	72±04^{fg}	87±11^{f}
	32	125±09^{e}	145±20^{e}	125±08^{e}
	40	209±19^{d}	216±18^{d}	229±09^{d}
	50	329±32^{a}	319±12^{b}	263±43^{c}
PM/BW(%) (n=8)	25	7.9±0.4^{g}	9±0.4^{fg}	10.2±0.7^{ef}
	32	10.8±0.6^{e}	13.3±1.5^{c}	11.1±0.9^{de}
	40	14.6±1.2^{b}	14.9±1.5^{b}	14.8±0.8^{b}
	50	16.6±1.3^{a}	16±1.1^{ab}	14.7±0.9^{b}
AF (g) (n=8)	25	7.90±1.34^{g}	8.68±1.10^{g}	8.89±0.67^{g}
	32	18.47±1.58^{e}	13.62±1.07^{f}	11.66±2.93^{f}
	40	28.50±2.60^{c}	21.02±1.48^{d}	21.65±3.75^{d}
	50	38.31±2.60^{a}	38.14±1.34^{a}	31.73±3.33^{b}
SCL (g) (n=8)	32	13±04^{g}	21±03^{f}	26±05^{ef}
	40	30±05^{df}	35±06^{d}	64±09^{b}
	50	57±06^{c}	53±06^{c}	104±11^{a}
SCL/EC (%) (n=8)	32	1.9±0.6^{g}	3.2±0.7^{ef}	4±0.6^{cd}
	40	2.8±0.4^{f}	3.4±0.6^{def}	5.6±0.6^{b}
	50	3.7±0.4^{cde}	4.2±0.4^{c}	7.3±0.6^{a}

Each result represents the mean value followed by standard deviation (SD). Mean values with different superscript letters were significantly different (P < 0.05). EC, Eviscerated carcass; BW, body weight; PM, pectoral muscle; AG, abdominal fat; SCL, subcutaneous lipids.

the development of the pectoral muscle (PM) which was significantly higher ($p < 0.05$) than that of NT chickens. Furthermore, no difference in PM weight was recorded in chickens of 32 days old, exposed to all three types of temperature. This trend continued until the 40th. At the end of rearing, a significant ($p < 0.05$) increase PM weight, linked to HT, was observed. These results have led to yields PM/BW) significantly lower in late breeding in HT chickens.

A SCL deposit significantly higher ($p < 0.05$) occurs in HT chickens from day 32. At the end of rearing, it reached a value almost twice of that of TN chickens exposed to other temperatures (104 g versus 57 for TN and 104 g versus 53 g for MT). These results have led to ratios of SCL/EC significantly higher ($p < 0.05$) in HT chickens mainly at the end of breeding with a value of For abdominal fat (AF), the trends were reversed Indeed, the AF was significantly higher ($p < 0.05$) in NT chickens

Table 4. Fatty acid composition of subcutaneous lipid of chickens exposed to the scorching temperature (HT) and to neutral temperature (NT) (in % of identified fatty acids).

Fat acid	Age (day)	Breeding temperature	
		NT	HT
$C_{16:0}$	40	27.55±0.43^{a}	27.74±0.63^{a}
	50	27.34±0.28^{a}	28.22±0.86^{a}
$C_{18:0}$	40	7.26±0.25^{a}	7.42±0.29^{a}
	50	6.26±0.23^{b}	7.52±0.17^{a}
$C_{14:0}$	40	0.47±0.01^{b}	0.59±0.12^{a}
	50	0.48 ±0.01^{b}	0.49±0.03^{b}
$C_{18:1}$	40	43.71±0.18^{b}	43.63±0.44^{b}
	50	44.75± 0.17^{a}	44.25± 0.92^{a}
$C_{16:1}$	40	6.93±0.5^{a}	6.07±0.35^{b}
	50	7.55±0.34^{a}	7.04±0.31^{a}
$C_{20:1}$	40	0.20±0.03^{b}	0.199±0.04^{b}
	50	0.33±0.09^{a}	0.22±0.03^{b}
$C_{18:2}$	40	13.18±0.59^{a}	14.16±0.48^{a}
	50	12.09±0.18^{b}	12.88±1.23^{b}
$C_{18:3}$	40	0.55±0.01^{a}	0.51±0.12^{b}
	50	0.48±0.06^{b}	0.50±0.07^{b}
$C_{20:4}$	40	0.16±0.02^{b}	0.17±0.04^{b}
	50	0.15±0.02^{b}	0.24±0.12^{a}
SFA	40	35.27±0.26^{a}	35.66±0.63^{a}
	50	34.06±0.25^{b}	36.23±0.89^{a}
MUFA	40	50.84±0.67^{b}	49.90±0.79^{b}
	50	52.63±0.39^{a}	51.51±1.25^{a}
PUFA	40	13.89±0.61^{a}	14.84±0.41^{a}
	50	12.72±0.12^{b}	13.62±1.36^{a}
SFA/UFA	40	1.84±0.15^{b}	1.80±0.21^{C}
	50	1.93±0.12^{a}	1.79±0.19^{C}

Each result represents the mean value followed by standard deviation (SD); n = 32. Mean values with different superscript letters were significantly different (P < 0.05).

from day 32 compared with HT chickens (28.5 versus 21.65 g and 38.31 g versus 31.73 g, respectively for days 40 and 50). At the end of rearing, no difference in Weight of AF was observed between NT and MT chickens.

Fatty acid composition of subcutaneous lipids

The fatty acid composition of chickens SCL exposed to HT and NT is shown in Table 4. Similar and high proportion of C18: 1 was recorded in HT and NT chickens more than 44% at the end of rearing. Nevertheless, a significant increase of C18: 1 ($p < 0.05$) with the age of animals was observed. No temperature effect with age on C16:0 proportions were found which remains the most predominant among the SFA (between 27.34 and 28.22%). Furthermore, a significant ($p < 0.05$) effects of HT on increasing of the C18: 0 and C20: 4 proportions were recorded at the 50th day (7.52 versus 6.26% for the first and 0.24 versus 0.15% for the second). At day 40, the HT resulted in a significant decrease ($p < 0.05$) in the C16: 1 proportion. Whatever the applied temperature, a significant decrease ($p < 0.05$) in the proportion of C18:2 were observed at the end of rearing. Regardless of rearing temperature and chickens age, very low proportions of C14:0, C20:1 and C18:3 are recorded.

Until the 40th day, no significant difference in the proportion of saturated fatty acids (SFA) was found in HT and NT chickens. In contrast, a significant increase ($p < 0.05$) in the SFA proportion of SCL was observed in HT chickens of 50 days compared with NT chickens. For the MUFA, their proportion had significantly increased ($p < 0.05$) with animals age and whatever the applied temperature. Thus, no temperature effect on MUFA is highlighted. At the end of rearing, the PUFA proportion of SCL is significantly ($p < 0.05$) higher in the HT chickens. Finally, the HT appears to have a negative and significant effect ($p < 0.05$) on the ratio UFA /SFA of SCL.

DISCUSSION

For the three types of rearing temperature tested, a gradual increase of FI was observed. Scorching temperature of 37°C had a depressing effect on FI mainly at the end of rearing. Indeed, between NT and HT treatment, insignificant FI differences of about 1 g/day were observed until the day 28. The difference was more important from the 40th day reaching a decrease of 7 or 0.58% per degree of temperature increase. The FI decrease under hot temperature was more pronounced at the end of breeding in comparison with NT, 24 or 2% per degree of temperature increase. These observations are similar to those obtained by other authors who worked on older chickens subjected to shorter exposures (2 to 3 weeks) at relatively lower temperatures (32 to 35°C) (Geraert et al., 1996; Bonnet et al., 1997; Mendes et al., 1997; Temim et al., 1999; Temim et al., 2000b; Abu-Dieyeh, 2006a; Al-Fataftah and Abu-Dieyeh, 2007; Gu et al., 2008). However, despite the low heat intensity and exposure duration, some authors have recorded a decrease in FI level per degree of temperature increase significantly greater in the order of 3.2% (Abu- Dieyeh, 2006a) and 2.6% (Gu et al., 2008). In contrast and compared with results from other authors, the effect of HT (37°C) on FI was more pronounced. Indeed, Mendes et al. (1997), Temim et al. (2000a) and Al-Fataftah and Abu-Dieyeh (2007) had noted smaller FI decrease of 1.41, 1.86 and 1.75% per degree, respectively.

Up to 40 days age, similar BW of HT and NT chickens were observed. At the end of rearing, a BW decrease associated with HT (4.3%) was recorded compared with NT. This BW decrease becomes greater when the temperature difference increases. In fact, at the 50th day, the decrease reached 8.8% between NT and HT. It should be noted that the depressive effect of HT on BW becomes more noticeable from the 40th day compared with NT. With relatively less warm temperatures and short exposures, BW decreases related to heat had already been reported by Bonnet et al. (1997), Temim et al. (1999), Abu-Dieyeh (2006b), Rosa et al. (2007), Al-Fataftah and Abu-Dieyeh (2007) and Gu et al. (2008). These results show that the growth rate of chickens decreases under the heat effect, even during few hours of exposure (Mujahid et al., 2009). It should be noted that more pronounced BW decreases have been recorded by these authors comparatively to chickens subjected to 37°C, varying between 18 and 29%. It is clearly shown that chickens exposed at an early age to HT are probably more adapted to great heat with consequent BW reductions moderately lower compared with those observed by other authors who submitted the chickens to temperatures similar to MT and at a later age (3 to 4 weeks).

Each result represents the mean value followed by standard deviation (SD Mean values with different superscript letters were significantly different ($P < 0.05$). UFA/SFA: Ratio of total unsaturated fatty acids to saturated fatty acids.

From day 14 to 40 breeding, DWG decreases were recorded in HT chickens reaching 23 and 37%, respectively compared with NT chickens. At the end of rearing, this decrease was less pronounced reaching 22%. At the 28th day and compared with NT chickens, DWG of HT chickens decrease was only of 7%. DWG related to heat had already been reported by several authors (Ain Baziz et al., 1996; Geraert et al., 1996; Cooper and Washburn, 1998; Temim et al., 1999; Abu-Dieyeh, 2006b; Lu et al., 2007; Gu et al., 2008). Despite the applied heat intensity (37°C) and longer exposure time, the DWG decreases remain lower than those of other authors. Indeed, Ain Baziz et al. (1996), Bonnet et al. (1997), Temim et al. (1999) and Lu et al. (2007) noted DWG of 47, 52, 49 and 64%, respectively.

The decreases in FI, BW and DWG associated with chronic exposure of chickens to great heat were likely to generate less efficient FCR. In effect, until the 28th day, the HT resulted by a significant FCR depreciation. Compared with NT, a lower FCR, due to HT was observed at the end of breeding (-17.7 and -15%, respectively for the 40th and 50th days). These results disagree with those obtained by Geraert et al. (1996), Furlan et al. (2004), Ozbey and Ozcelik (2004), Nasseem et al. (2005), Abu-Dieyeh (2006a), Gu et al. (2008) and Ghazalah et al. (2008) who observed less effective FCR attributed to great heat. FCR increases, ranging from 28 and 53.7% were observed by Geraert et al. (1996), Bonnet et al. (1997), Abu-Dieyeh (2006a) and Gu et al. (2008). In contrast and compared with our results, Aengwanich (2007) observed a better FCR after 6 h exposure to a temperature cycle of 26 to 38°C. This was partly explained by the chicken behavior at the end of rearing, which tends to limit the FI under great heat.

Whatever their age, HT chickens gave significantly lower EC weight compared with those exposed to the other temperatures. By age, the decrease was between 3 and 14%. Between the MT and HT, the EC weight difference was lower, reaching 3.9% at the end of rearing. Furthermore, more pronounced decreases of carcass weight attributed to heat have already been reported by Ain Baziz et al. (1996) and Gu et al. (2008) (29 and 24% respectively). On carcass yield (EC/BW), fluctuations were observed regarding the temperatures and age of animals. However, the best EC/BW were obtained at the end of breeding in chickens exposed to MT et HT. Ain Baziz et al. (1996), Rosa et al. (2007), Lu et al. (2007) and Gu et al. (2008) had reported an increase in carcass yield of between 1.45 and 2.58% in chickens exposed to heat. This increase in carcass yield, due to higher temperatures, is partly attributed to the reduction of digestive tract caused by the FI decrease (Bonnet et al., 1997). Despite conflicting results, it could also be explained by the decrease in the plumage proportion (Geraert et al., 1993, 1996).

Until the 25th day, temperatures TM and TC appear to be beneficial for the weight of pectoral muscle (PM). In fact, at this age the PM weight was significantly higher in chickens exposed to MT and HT (+5.5 and +26.4%, respectively). Between the 25th and 40th day, no difference in PM weight was observed in chickens exposed to three types of temperature. This shows a decrease in the PM weight during the animals growth related to heat. This decline was more pronounced with TC especially at the end of breeding (-20% between NT and HT). These results were reflected in yields (PM/BW) significantly lower at the end of breeding in HT chickens (-11.4% between NT and HT). Similar observations were reported by other authors. Thus, the decreases of PM weight of about 18, 23 and 33.4% were recorded respectively by Temim et al. (1999), Temim et al. (2000b) and Gu et al. (2008). Likewise, similar PM weight decreases related to heat waves were also reported by Ain Baziz et al. (1996), Mendes et al. (1997), Rosa et al. (2007) and Gu et al. (2008) (11.2, 8.9, 9 and 12.8%, respectively). Compared with temperatures (32 to 35°C) applied by these authors, we find that PM weight decreases recorded in chickens reared since the first age at 37°C does not appear to be dramatic and do not exceed 20%. It is possible that these results are associated with inadequate FI, thereby reducing the synthesis and glycogen storage considered the most important energy source for PM (Geraert et al., 1996). Thus, Aksit et al. (2006) had described a PM decrease of 1.5% and a lower glycogen level in the chickens of 42 days exposed to 34°C. Finally, Ain Baziz (1996) observed a 7% energy reduction retained as protein in chickens exposed to 32°C.

From the 32th day, exposure to HT caused a SCL deposit significantly higher in chickens. This deposit was accentuated in the late breeding averaging 104 g by chicken, about double of those of chickens subjected to other types of temperature. This led inevitably to EC fatter since the SCL/CE ratio was significantly higher in chickens exposed to HT mainly at the end of breeding with a value of 7.3%. Ain Baziz et al. (1996), Tesseraud and Temim (1999) and Lu et al. (2007) had observed conflicting results in chickens exposed to warm temperatures. Increases in SCL associated with heat were recorded in Ain Baziz et al. (1996) and Tesseraud and Temim (1999) about 21 and 17.26%, respectively. In contrast, Lu et al. (2007) had noted a SCL decrease of 19.5% in chickens after three weeks of exposure to 34°C. According to Ain Baziz (1996), increased deposition of SCL does not appear to be attributed to hyperplasia, since the number of adipocytes was significantly lower in chickens kept at 32°C and fed *ad libitum*. However, it may be related to hypertrophy of adipocytes since 70% of these fat cells had a larger diameter, between 80 and 120 µm. This increase in SCL, due to heat, could also be explained by increased lipogenesis, mainly from carbohydrates, the main constituent of feed given *ad libitum*. According to Ain Baziz et al. (1996), a great heat causes a decrease in the activity of lipogenic enzymes in the liver, which suggests that the adipose tissues such as skin may be the sites of lipid synthesis and energy storage as fat. Moreover, Geraert et al. (1996) had found a 17% increase of retained energy as fat in chickens subjected to heat.

Unlike SCL, the AF deposition was significantly higher among NT chickens. This increase was important up the 32th day, in the order of 36.9% compared with HT. It gradually decreases to 17% by the end of rearing. Similar observations were reported by Ain Baziz et al. (1996), Temim et al. (2000b) and Gu et al. (2008) who found decrease in AF in chickens exposed to heat (10.7, 9.13 and 7.1%, respectively). It should be noted that with the HT, the decrease in AF was significantly higher compared with that observed by other authors who used moderately warm temperatures and shorter exposure times.

The early and prolonged exposure to HT leads to some modifications of fatty acid composition of SCL in chickens, especially at the end of rearing. Indeed, with the HT, the SCL-old chickens of 50 days contain more

C18:0 and C20:4 but less C20:1. Similarly, the proportions of SFA and PUFA were higher in the HT chickens. By contrast, no effect of temperature was recorded on the MUFA, which however, increase with age. At 50 days, the UFA/SFA ratio was lower in HT chickens, resulting in a higher degree of saturation of SCL. Same trend of the UFA/SFA ratio has been observ-ed by Ain Baziz (1996) in chickens exposed to 32°C. However, Ain Baziz (1996) had recorded the UFA/SFA ratios higher to ours in chickens exposed to 32 and 22°C. The proportions of SFA (36%) and MUFA of SCL of HT chickens were higher than those of Ain Baziz (1996).

Finally, the increase in subcutaneous adiposity, driven by HT, could contribute positively to a drop of the "oily syndrome" as the ratio UFA/SFA is clearly higher reflecting a degree of lipid saturation more important which therefore, improves the concentration of subcutaneous fat. We must remember that this "oily syndrome" of chicken carcasses has long been criticized by slaughter industry and grill room professionals, especially in summer.

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