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Original article

Comparison of carcass composition by parts and tissues between cocks and capons

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Abstract — The effect of caponisation on carcass composition by parts and tissues was examined. Twenty-eight castrated and twenty male Penedesenca Negra chicks reared under free-range conditions were slaughtered at 28 weeks of age. The birds were castrated at 4 or 8 weeks. The left sides of the carcasses were quartered (wing, breast, thigh and drumstick), and the parts dissected into the tissue components (skin, subcutaneous fat, intermuscular fat, muscle, bone and tendons). Capons showed more abdominal, intermuscular and subcutaneous fat than the cocks, both at the same slaughter age and at the same weight. The breast and thigh were heavier in the capons than in the cocks. However, the whole muscle mass in the breast was increased by caponisation. This favourable effect was achieved at the expense of decreasing the carcass yield. The age of castration up to 8 weeks did not affect the carcass composition of the parts and tissues.

chicken / capon / carcass / tissue composition

Résumé — Comparaison du rendement à la découpe et de la composition tissulaire des carcasses de coqs et de chapons. Vingt huit chapons et vingt coqs de la race Penedesenca Negra ont été élevés sur parcours et abattus à l'âge de 28 semaines. Le chaponnage des poulets a été réalisé à deux âges différents : 4 ou 8 semaines. Après l'abattage, les morceaux (aile, pilon, cuisse et filet) correspondant à la moitié gauche de la carcasse ont été prélevés et disséqués en séparant la peau, le tissu adipeux sous-cutané, le tissu adipeux intermusculaire, les muscles, les os et les tendons. Par comparaison avec les coqs abattus au même âge ou de même poids, les chapons présentent une quantité de gras abdominal sous-cutané et intermusculaire plus élevée. Le poids de leur filet est également supérieur. En revanche, leur rendement en carcasse est inférieur. L'âge au chaponnage n'a pas d'effet sur le rendement à la découpe, ni sur la composition tissulaire de la carcasse.

coq / chapon / carcasse / composition tissulaire

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1. INTRODUCTION

In recent times there has been an increase in the consumer's demand for more variety and quality of poultry meat products. This has led to reappraise the use of local breeds and traditional practices, such as caponisation. The production of castrated male chickens (capons) for high standard markets has a long tradition in some Mediterranean countries, particularly in France, where labelled capons account for around 1.5 millions of units [29]. In accordance with popular perception, some early works have shown that meat from capons is really more tender [20] and more appreciated by consumers [32].

The main effect of caponisation is to increase the overall fatness. Fatness is a trait of great concern to both poultry breeders and retailers because the production of fat is less efficient and decreases the economic value of the carcass. But in contrast, fatness may play an important role in meat quality and therefore in the consumer's preference. It has been observed that intramuscular fat content is associated with the overall acceptability of chicken meat [33], a fact widely observed in other species like pigs [8]. It is well known from the literature that capons tend to deposit more abdominal fat than cocks [2], in a similar way that occurs in females with respect to males [19, 28]. Although the abdominal fat is positively correlated with overall fatness [1], little is known concerning the effects of caponisation on the relative ratios between fat depots.

The purpose of the present work was to investigate the effects of caponisation on carcass composition of parts and tissues, with emphasis on the adipose tissue distribution. The results of this study should give a more complete basis for discrimination and choice among poultry meat products. In this study, we used the Penedesenca Negra breed [11], a local poultry breed from Catalonia, Spain, which is nowadays being introduced as a genetic resource for high quality poultry products.

2. MATERIALS AND METHODS

The experimental procedures conducted in this study were approved by the Ethic Committee for Animal Experimentation of the University of Lleida.

2.1. Animals and rearing procedures

Three hundred and seventy six male Penedesenca Negra-based birds from the IRTA Poultry Genetic Conservation Program [11] were placed into two batches after hatching. All chicks were vaccinated at hatching against Marek disease and brooded for 28 days in electrically heated batteries. Following the brooding period, the chicks were reared until 28 weeks of age in single-compartment floor pens (1.5 birds per m^2) under free-range conditions. The diets were formulated according to the official requirements of quality poultry production in Catalonia, Spain [6].

During the trial, two 70%-cereal based diets were administered ad libitum. The first one was fed from 0 to 6 weeks (23.5% CP, 12.95 MJ ME per kg DM) while the second from 7 to 28 weeks (20.7% CP, 13.37 MJ ME per kg DM). In each batch, around half of the birds were castrated according to the traditional caponisation practice in Spain. In the first batch, caponisations were performed at 4 weeks (early caponisation; CA-4) or at 8 weeks of age (late caponisation; CA-8) while in the second batch all castrations were done at 8 weeks of age. Before slaughter, 20 CA-8 and 20 cocks (CK), evenly distributed over the two batches, were randomly selected for carcass dissection. Also, to determine the effect of the age of caponisation on carcass characteristics, 8 CA-4 from the first batch were sampled. This age was chosen because it is the earliest age in which castration can be easily practised under farm conditions.

All birds were caponised bilaterally using the surgical method described in Cubiló and Tor [3]. Early castrated chicks, late castrated chicks, and cocks were kept in separate pens. The absence of testicular regeneration in castrates was determined on live birds by visual assessment and confirmed later after slaughtering.

2.2. Carcass dissection and tissue composition

The animals, at 28 weeks of age, were stunned, slaughtered, bled and pluck in a commercial slaughterhouse. The carcasses containing the abdominal pads were chilled in a 4 °C cool room for 24 h. The day after, the left side of the carcasses were quartered according to the WPSA reference cutting method [12] and abdominal fat was obtained after removal from the whole abdominal pad. The left wing, breast, thigh, and drumstick were dissected into the following tissue components: skin, subcutaneous fat, intermuscular fat, muscle, bone and tendons. All the weights of tissues were recorded individually on a part basis. The carcass composition by tissues was calculated as the sum of the weight of each tissue component (skin, subcutaneous fat, intermuscular fat, muscles, bones and tendons) from the dissected parts per unit sum of all the dissected components of all the dissected parts. The composition of each part was calculated as the weight of each tissue component per unit sum of all the dissected components of the part.

2.3. Statistical analyses

Analyses for the weight of the individual parts and their tissue components, as well as carcass composition by tissues variables, were performed according to the following model:

$$Y_{ijk} = \mu + b_i + s_j + bX_{ijk} + e_{ijk} \qquad (1)$$

where Y_{ijk} is the observation of individual k in batch i of sexual group j; μ is the overall mean; b_i is the batch effect i (i: 1, 2); s_j is the sexual group effect j (j: CA, CK); b is the regression coefficient for X_{ijk}, and e_{ijk} is the residual error term. The covariable X_{ijk} was included in the model in order to adjust the differences between sex groups in live weight at the age of slaughter. Thus, X_{ijk} is the live weight at slaughter of the individual k. The covariate was removed from model (1) when sexual group effects were compared at the same age. To test the effect of age of caponisation, a previous analysis was performed using only data from the first batch. The model used in this case was the same as that described above but instead of the effects of batch and sex, the effect of the age of caponisation (CA-4, CA-8) was included.

The analysis for part composition by tissues was done using the following model:

$$Y_{ijkl} = \mu + b_i + s_j + p_k + sp_{jk} + bX_{ijkl} + e_{ijkl} \qquad (2)$$

In model (2) Y_{ijkl} is the tissue component in part k from individual l of batch i and sexual group j. Besides the effects of batch and sex, the effects of part p_k (k: wing, breast, thigh, drumstick) and the interaction between sexual group and part sp_{jk} were also included. In this model, the covariate X_{ijkl} was the part weight.

All analyses were performed using the SAS general linear model (GLM) procedure [26]. The analyses provided estimates of treatment contrasts. Statistical significance of the differences was determined by the t-test.

3. RESULTS

The mortality induced by castration was around 1% and testicular regeneration reached

28%. No relevant differences between early and late castration were found, neither in carcass weight distribution nor in carcass tissue distribution (Tab. I). Only the skin percentage was significantly modified by the age of castration, being higher in CA-4 than in CA-8 capons. Taking this into account, in our study the age of caponisation did not have relevant effects on carcass distribution and composition. All results from here on will include capons as a single group effect, irrespective of the age they were caponised.

3.1. Carcass weight and part weight distribution

The effect of caponisation on carcass composition by parts is given in Table II. Caponisation increased ($P < 0.001$) live weight at slaughter age (28 weeks) but not carcass weight. This difference was largely due to abdominal fat, which was much higher in capons ($P < 0.001$). In consequence, caponisation led to lower eviscerated carcass yields, either at the same slaughter age (72.60% ± 0.45 and 77.66% ± 0.49 in capons and cocks, respectively) or at the same weight (72.73% ± 0.50 and 77.51% ± 0.56 in capons and cocks, respectively). Moreover, carcass composition by parts was affected by caponisation. Thus, while the breast ($P < 0.001$) and the thigh ($P < 0.01$) were heavier in capons, the drumstick was heavier in cocks ($P < 0.05$). However, the wing did not differ between capons and cocks. The greater development of the breast in capons was maintained even after adjusting for live weight ($P < 0.05$).

3.2. Carcass composition by tissues

Carcass composition by tissues differed between cocks and capons (Tab. II). Capons had higher percentages of subcutaneous and intermuscular fat ($P < 0.001$) while cocks had higher percentages of skin ($P < 0.001$), muscle ($P < 0.001$), bone ($P < 0.001$) and tendons ($P < 0.05$). No relevant changes

Table I. Least squares means and residual standard deviation of carcass composition by parts and tissues at 28 weeks of age in capons castrated at 4 and 8 weeks.

	Caponisation[1]			
	Early (n = 8)	Late (n = 8)	RSD	Significance[4]
Carcass composition by parts *(g)*				
Live	3757	3687	248	ns
Abdominal fat	271.4	290.3	82.3	ns
Carcass	2696	2613	175.3	ns
Breast[2]	300.4	294.0	35.8	ns
Wing[2]	122.2	119.3	7.0	ns
Thigh[2]	316.3	294.9	33.0	ns
Drumstick[2]	170.3	171.3	13.1	ns
Carcass composition by tissues *(%)*[3]				
Skin	7.69	6.19	1.34	*
Subcutaneous fat	14.48	15.92	5.67	ns
Intermuscular fat	2.49	2.52	0.36	ns
Muscle	64.64	65.07	5.06	ns
Bone	8.81	8.51	0.73	ns
Tendons	1.86	1.77	0.21	ns

[1] Early at 4 weeks, late at 8 weeks; [2] Left side parts; [3] Carcass composition by tissues was calculated from tissue composition of the left wing, breast, thigh and drumstick of the carcass; [4] ns: not significant; *: $P < 0.05$.

Table II. Least squares means and residual standard deviation of carcass composition by parts and tissues in cocks and capons.

	Equal slaughter age[1]		RSD	Significance[4]	Constant live weight[1]		RSD	Significance[4]
	Cocks (n = 20)	Capons (n = 28)			Cocks (n = 20)	Capons (n = 28)		
Carcass composition by parts[2] (g)								
Live	3313	3713	278	***	..	..		
Abdominal fat	47.7	305.9	84	***	88.4	259.5	55.1	***
Carcass	2582	2727	252	ns	2738	2567	75	***
Breast[2]	265.1	347.9	50.1	***	292.5	318.0	31.0	*
Wing[2]	118.6	123.9	10.5	ns	124.1	118.4	6.1	*
Thigh[2]	267.1	305.2	38.4	**	289.2	282.6	17.3	ns
Drumstick[2]	189.9	177.8	18.2	*	199.1	168.4	11.5	***
Carcass tissue[3] composition (%)								
Skin	8.92	6.20	1.21	***	8.97	6.24	1.27	***
Subcutaneous fat	5.37	18.73	4.54	***	6.76	17.41	4.21	***
Intermuscular fat	1.58	2.17	0.30	***	1.58	2.18	0.31	***
Muscle	72.14	62.39	3.70	***	70.96	63.46	3.47	***
Bone	9.69	8.41	0.72	***	9.46	8.65	0.65	**
Tendons	2.29	2.07	0.28	*	2.25	2.04	0.26	*

[1] Slaughter age was 28 weeks and live weight was adjusted at 3.5 kg adjusted according to the model (1); [2] Left side parts; [3] Carcass composition by tissues was calculated from tissue composition of the left wing, breast, thigh and drumstick of the carcass; [4] ns: not significant; *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

were found when live weight was added in the model as a covariate. The effect of caponisation on carcass composition by tissues (Tab. III) was part dependent. A significant caponisation with a part interaction effect was found for all the studied tissues except tendons. Therefore, the effect of caponisation on carcass composition according to the tissues is given part by part. As depicted in Figure 1, the effect of caponisation on tissue composition was consistent in all the parts, though it may differ in grade from part to part. Thus, capons had lower percentages of skin in every part, the highest differences being in the breast (– 4.38%, $P < 0.001$) and the drumstick (– 2.72%, $P < 0.001$). Both subcutaneous and intermuscular fat were always higher in capons than in cocks, with the thigh displaying the greatest difference (14.17%, for subcutaneous fat ($P < 0.001$), and 13.1%, for intermuscular fat ($P < 0.001$)). Muscle percentage was lower in capons than in cocks for the breast (– 3.82%, $P < 0.01$), the thigh (– 12.48%, $P < 0.001$) and the drumstick (– 2.72%, $P < 0.05$). This led the capons to produce less weight of muscle in the thigh ($P < 0.01$) and in the drumstick ($P < 0.01$) but not in the breast, where the muscle mass was still greater ($P < 0.05$) in the capons (Tab. IV). The bone percentage was not modified by caponisation except for the wing, where capons had slightly lower percentages of bone than cocks (– 1.3%, $P < 0.01$). Neither of the studied parts presented any effect of caponisation on tendon percentages (Fig. 1). The correlation structure between live, carcass and abdominal fat weight with carcass tissue components in cocks and capons is given in

Table III. Statistical significance of the effects of caponisation, part, interaction between caponisation and part, and part weight on tissue composition.

Carcass composition by tissues (%)	Effect				
	Mean	Caponisation	Part	Caponisation × part	Part weight
Skin	8.50	***	***	***	ns
Subcutaneous fat	11.04	***	***	***	***
Intermuscular fat	1.99	***	***	***	*
Muscle	63.70	***	***	***	***
Bone	16.17	ns	***	**	***
Tendons	2.65	ns	***	ns	ns

ns, *, **, ***: non significant, significant at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively. Analyses were performed according to model (2).

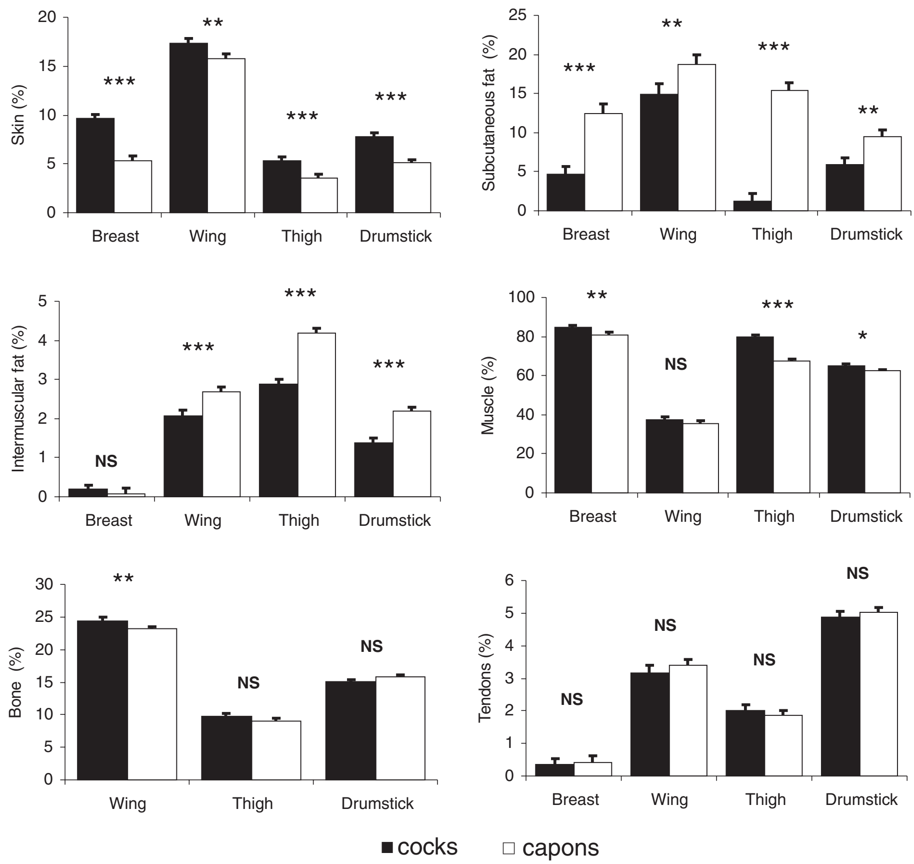

Figure 1. Least square means and S.E. (⊤) of tissue composition by part. (*, **,*** significant at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively) for cocks and capons slaughtered at the same age.

Table IV. Least squares means and residual standard deviation of fat and muscle contents of the left part at 28 weeks of age in cocks and capons.

Part	Fat[1] (g)		RSD	Significance[2]	Muscle (g)		RSD	Significance[2]
	Cocks (n = 20)	Capons (n = 28)			Cocks (n = 20)	Capons (n = 28)		
Breast	21.38	94.23	39.01	***	216.17	232.99	23.24	*
Wing	6.98	13.73	3.71	***	56.81	56.51	5.31	ns
Thigh	23.16	84.42	23.70	***	201.81	182.15	22.42	**
Drumstick	6.94	11.81	3.77	***	130.04	119.30	12.83	**

[1] Subcutaneous + Intermuscular Fat; [2] ns: not significant; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

Table V. Correlations between live weight, abdominal fat weight, carcass weight and carcass composition within cocks (upper diagonal) and capons (lower diagonal).

	LW	AF	CW	SK	SB	IM	M	B	SW
LW	··	0.56*	0.91**	–0.25	0.43	0.09	–0.32	–0.31	–0.21
AF	0.77***	··	0.46*	–0.43	0.60**	0.50*	–0.45*	–0.47*	–0.27
CW	0.94***	0.79***	··	–0.34	0.62**	–0.00	–0.51*	–0.34	–0.14
SK	0.21	–0.28	–0.05	··	–0.43	–0.40	0.04	0.38	0.25
SB	0.36	0.79***	0.48**	–0.50**	··	0.09	–0.89***	–0.51*	–0.02
IM	–0.12	–0.15	–0.25	0.28	–0.39*	··	0.03	–0.05	–0.50*
M	–0.42*	–0.78***	–0.50**	0.29	–0.96***	0.32	··	0.21	–0.21
B	–0.45*	–0.79***	–0.52**	0.39*	–0.84***	0.28	0.77***	··	0.41
SW	–0.16	0.03	0.20	–0.18	0.09	–0.50**	–0.11	0.10	··

LW: Live weight; AF: Abdominal fat; CW: Carcass weight; SK: Skin %; SB: Subcutaneous fat %; IM: Intermuscular fat %; M: Muscle %; B: Bone %; SW: Tendons %; *, **,*** Significant at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively.

Table V. It can be summarised in two points. First, carcass weight, which was positively correlated with abdominal fat in both capons ($P < 0.001$) and cocks ($P < 0.05$), was negatively correlated with the percentage of muscle. Second, the correlation of the abdominal fat with the subcutaneous fat was positive and higher in capons ($P < 0.001$), but the correlation with the intermuscular fat, although positive as well, was only relevant in cocks ($P < 0.05$).

4. DISCUSSION

4.1. Age of caponisation

Rahman et al. [25] showed that the effects of gonadal development on fat deposition may start very early in time. However, it should be remarked that their results were found in broilers, which show a very different growth pattern from the Penedesenca

Negra genetic type used in this study. At 4 weeks of age, broilers were 1.6 times more mature than Penedesenca Negra cocks reared under the same conditions [31]. Our results would indicate then that the effects of an early castration on carcass distribution and carcass composition by tissues would be less obvious in slower growing breeds, like Penedesenca Negra, in which the age of castration can be delayed up to 8 weeks without remarkable consequences on carcass traits. On the contrary, the difference encountered between the ages of castration in the skin percentage would suggest that the skin is the first and the most sensitive tissue component to be feminised.

4.2. Carcass weight and part weight distribution

Abdominal fat increased more than six-fold in capons and explained two thirds of the difference in live weight between capons and cocks. It is well known from the literature that caponisation increases the abdominal fat pad, regardless of the breed and the age at which the capons are slaughtered [2, 10, 21]. However, the effect of caponisation on live weight is not so clear. Thus, some studies reported a positive effect of caponisation on live weight [20, 32] whereas others did not find any effect [21, 34] or even that cocks were heavier than capons [2]. In a previous study we showed that capons and cocks have a similar growth curve up to 19 weeks but from that moment on, capons begin to grow faster [5]. In our experiment capons and cocks were slaughtered at an age very close to maturity, where the maximum difference for live weight in favour of capons is expected. The lower live weight observed in cocks might be due to the fact that androgens in chickens, unlike mammals, are not anabolic [7]. Thus, the decline in growth caused by the androgenic stimulation of sexual behaviour would not be counterbalanced by the corresponding anabolic effect on growth. Carcass and abdominal pad weight differences between sexual groups were also calculated after adjusting for live weight. In this case, the abdominal fat pad weight still remained higher in capons but the carcass weight now was higher in cocks.

On the contrary, the part distribution changes as a consequence of caponisation were in good agreement with the results of Cubiló et al. [4], who reported a higher carcass perimeter and wider chest angle in capons and supported those in Francesch et al. [10], who found that caponisation increases the breast muscle mass. Thus, with respect to carcass characteristics, our results showed that caponisation improves the carcass conformation at the expense of decreasing the carcass yield. This latter effect, however, is to some extent counterbalanced by a correlative increase in the live weight of capons at the same age.

4.3. Carcass composition by tissues

The effect of caponisation on fatness occurred in all adipose tissues, in accordance with the results in Ono et al. [21]. However, we found that the skin percentage was higher in cocks than in capons. This observation disagrees with what would be expected from the results obtained after castration at different ages (Tab. I). The literature concerning this point is very scarce and difficult to interpret properly, since it is not always clear whether the skin is completely free of subcutaneous fat. Thus, when both tissues are considered jointly, the cocks showed the lower percentage (15.73 ± 1.00 and 23.65 ± 0.92 in CK and C, respectively). These figures coincided with those reported by Ono et al. [21] and Osman et al. [23] when comparing, respectively, capons and cocks, and cocks and hens for skin percentage.

To our knowledge, the present study is the only available in the literature concerning the differences between cocks and capons in tissue composition on a part basis. In mammals, some results point out that there is a differential effect of castration on tissue composition according to the part. Thus, Fisher et al. [9] reported differences between barrows and gilts in the lean percentage of leg but not in the shoulder. On the contrary, we observed that the effect of caponisation on fat accretion was higher for subcutaneous than for intermuscular fat, both in the whole carcass (Tab. II) and in every part (Fig. 1). Those capons had more subcutaneous fat might be due to the fact that the effects of caponisation occur during a period in which subcutaneous fat is more actively synthesised than intermuscular fat. In favour of this hypothesis is the fact that in mammals the growth pattern of the subcutaneous fat is delayed as compared to that of the intermuscular fat [14].

The fact that changes in muscle percentage between cocks and capons are partly dependent reinforces the conclusions of Ono et al. [22], who pointed out that caponisation delays muscle growth, especially in the femoral area. The bone and the tendons taken together may be considered as the more stable tissue components of the carcass after caponisation. This is in accordance with the early work of Landauer [18], who proved that caponisation in fowl does not modify skeleton measurements. In either case, our results indicate that the differences in fat distribution among parts are at the origin of the changes occurring in the part tissue composition of capons.

The correlation structure (Tab. V) between live and carcass weight with carcass composition by tissues confirm that at 28 weeks of age, growth is dominated by fat accretion but also suggests that the capacity of continuous growing of intermuscular fat is nearly exhausted at this age, particularly in capons. On the contrary, this capacity is still maintained for the subcutaneous and the abdominal fat. In fact, in pigs, Kouba et al. [17] pointed out that the development of intermuscular fat might be determined at an early stage and, relative to total fat, it is the adipose tissue that grows more slowly. Moreover, we observed that in capons unlike cocks, carcass weight was more correlated with abdominal fat than with subcutaneous fat. This supported the hypothesis that, at slaughter age, the abdominal fat is the adipose tissue that is growing more rapidly in capons whereas it is the subcutaneous fat in cocks.

It is known that there are sex differences regarding abdominal fat deposition in poultry. Thus, females tend to deposit more abdominal fat [19] and at a much faster rate than males [28]. Nonetheless, there is less information about the specific effect of gonadal hormones on the overall fat deposition and fat metabolism. It is known that the growth hormone has an antilipogenic effect in poultry [30] and that there is a sexual dimorphism in GH secretion [15]. Although the secretion pattern of the growth hormone can be feminised by early orchidectomy [24], it is not clear whether the androgenic control of the growth hormone is still active in castrations occurring at ages beyond 40 days [27]. On the contrary, caponisation causes a decrease in the hypophysis activity [24] and therefore may have an effect similar to that observed in hypophysectomised cockerels, which show an increased rate of hepatic lipogenesis [16]. As in chickens the adipose tissue is mainly originated in the liver [13], differences in hepatic lipogenesis may contribute to providing an explanation for the differences in the tissular composition of meat between capons and cocks. Further investigations are still necessary to gain insight into the hormonal changes in capons and their relationships with fat metabolism.

5. CONCLUSIONS

This study confirmed that the major effect of caponisation is on fat deposition. Capons have more abdominal fat but also more intermuscular and subcutaneous fat, at both the same slaughter age and the same weight. The increase in fatness is particularly high in the breast and in the thigh, the two parts where capons perform better than cocks. Nonetheless, caponisation increases the muscle mass in the breast. This favourable effect is achieved at the expense of decreasing the carcass yield. Therefore capons will only result in higher financial returns in markets where high-priced cuts of good quality are well appreciated. The age of castration up to 8 weeks does not affect carcass composition by parts and tissues, at least in slower-growing breeds.

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