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CARCASS TRAITS AND MEAT QUALITY OF RABBITS FED REGIMENS CONTAINING CAROB PODS AND REARED UNDER TUNISIAN SUMMER CONDITIONS

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ABSTRACT

This study aims to evaluate the effects of feed incorporation of Tunisian local carob pods, on meat quality. A growth performance assay was carried out in summer (July-August), on a total of one hundred twenty weaned four weeks of age New Zealand rabbits and weighing 607 ± 13 g. Animals were housed in 60 cages (2 rabbits/cage). Two iso-proteic and iso-energetic diets ("Control": without carob and "Carob": 20% carob) were formulated and each diet was allotted to a group of sixty rabbits (thirty cages x two rabbits). Growth performance was registered and fifteen male rabbits per diet of 11 weeks of age; were slaughtered and processed, to analyze the effects of diets on carcass traits. Growth performance data did not reveal any difference between group ($p>0.05$) and viability was significantly improved with carob ($p<0.01$), besides the high registered temperatures. Carcass traits showed similar carcass yields and higher proportions of the liver and the empty stomach and colon. In addition carob improved protein content and reduced fat in BF meat. In conclusion, carob pods can be incorporated in growing rabbit's diets at 20% without any negative incidence on carcass traits. It may also improve the viability of rabbits reared in hot climate.

Keywords: rabbits, carob, carcass quality, meat quality.

1. INTRODUCTION

Rabbit meat production in Tunisia, is around 2300 T (OEP, 2018). This production, compared to countries such as Algeria, Italy and France, is relatively low. Indeed, rabbit meat consumption is marginal (0.250 kg/capita/year) (GIPAC, 2018). Nonetheless, there's a growing interest among Tunisian trend consumers, in healthy food and in the near future the interest to rabbit meat will increase among Tunisian society (GIPAC, 2018). Notwithstanding, the high cost of imported raw materials such as soybean meal, grains or alfalfa meal; is one of the most important challenges that rabbit production sector is facing in Tunisia. Hence, in this context, local feed resources valorization could be an alternative to substitute imported raw materials in rabbit feeds. In view this background, we were interested in carob pods. Carob tree (*Ceratonia siliqua L.*) is an agro-sylvo-pastoral dioecious tree of the fabaceae family, which is well adapted to climatic risks and long drought periods. Thanks to its adaptation properties to water constraints, this tree

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is easily installed in arid and semi-arid zones. In Tunisia, carob trees occupy wet, sub-humid, and semi-arid upper floors, with a hot to temperate variant. It is mainly found along the Tunisian coast. FAOSTAT (2018) reported 850 T of pod production in Tunisia in 2016. Carob is widely used in Mediterranean region for nutritional, medicinal, ornamental, environmental and industrial purposes. Kotrotsios et al. (2012) reported that carob pods were also used in animal feeds. They are rich sources of sugars and gross energy but their high content of tannins, constrains its use in this field.

In the present study, we aim to evaluate essentially the effects of carob pods incorporation at 20% in feeds on carcass and meat quality of growing rabbits reared under Tunisian summer conditions.

2. MATERIALS AND METHODS

2.1. Environmental conditions during the assay

This study was conducted in the experimental farm of the higher institute of agricultural science of Chott Mariem, during a period of 49 days extended between 11th of August to 22nd of September. The area is located in the eastern central coast of Tunisia in the latitude of 35°56'17'' N and the longitude 10°33'18''E. Animals were housed in a static ventilation hutch where inside temperature and humidity were recorded daily (figure 1).

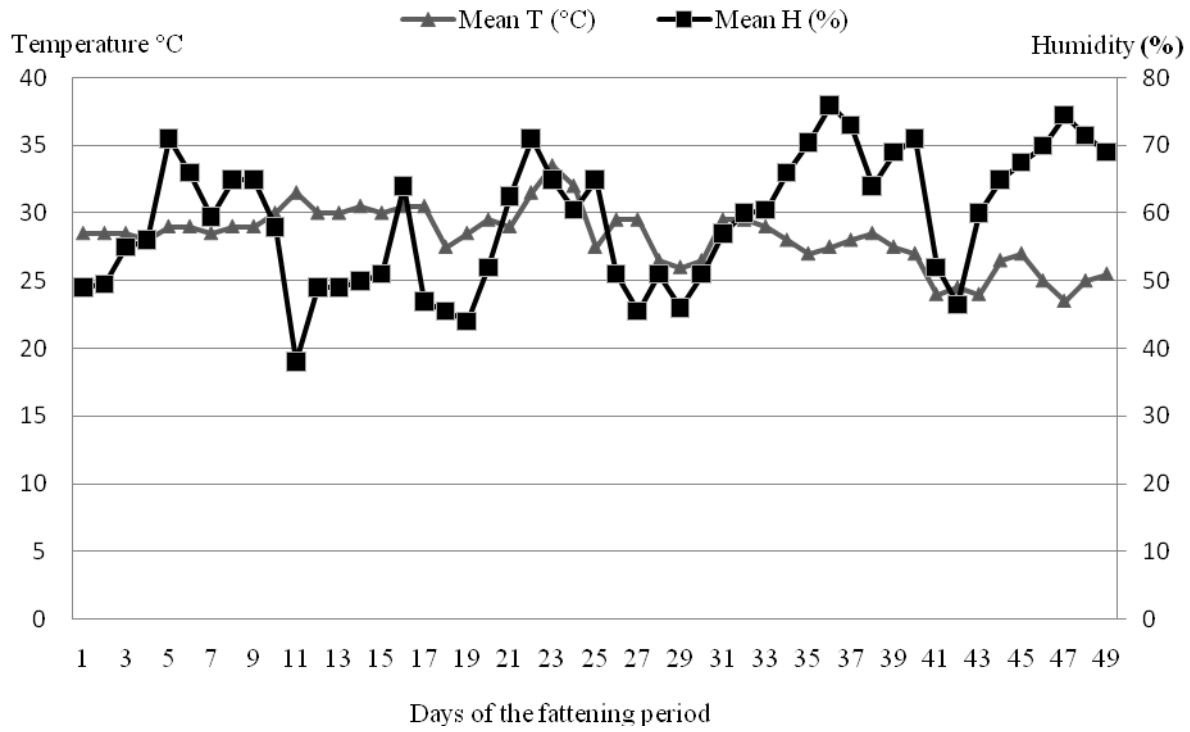

Figure 1: Humidity (%) and temperature °(C) variation

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2.2. Animals

One hundred twenty weaned 28 days of age male and female New Zealand rabbits, with an average initial body weight 607 ± 13g, were randomly divided into two homogeneous groups and housed in flat-deck wired cages of 76 cm of length, 45 cm of width and 25 cm of height and each cage is made up of two rabbits (male and female). All procedures were achieved under Law No. 2005-95 of the Tunisian Agriculture and Water Resources Minister for livestock and animal products.

2.3. Diets

Rabbits fed *ad libitum* isoenergetic and isoproteic diets: control diet and carob diet in which 20% carob was introduced until the end of the trial (11 weeks of age). Raw material components and chemical composition of the experimental diets are reported in Table 1.

Table 1: Feeds composition and nutritive value of Control and Carob diets and Carob pods(%)

	Control diet	Carob diet	Carob pods
Barley	40.6	23	-
DDGS Maize	10	11	-
Soybean meal	16	19	-
Alfalfa hay	32	25.6	-
Carob pods	0	20	100
Calcium carbonate	0.2	0.2	-
Monocalcic phosphate	0.2	0.2	-
Sodium Chloride	0.5	0.5	-
DL-Methionine	0.05	0.05	-
L-Lysine	0.02	0.02	-
Premix*	0.5	0.5	-
DM (%)	92.9	92.5	86.5
OM (% DM)	91.7	92.1	96.9
CP (%DM)	19.89	20.25	5.31
EE (% DM)	2.86	2,64	0.42
CF (%DM)	15.13	14.63	8.96

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NDF (%DM)	35.43	34.93	28.26
ADF (%DM)	16.6	19.7	27.00
ADL (%DM)	3.2	7.3	18.70
Condensed Tannins	-	-	1.90
DE (kcal/kg)	2422	2417	1850

DM: Dry matter; OM: Organic matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; ADL: Acid detergent lignin; DE: Digestible energy
*Premix Composition contains (g/kg premix): Zn, 7; Mg, 5; Mn, 5; Cu, 2.3; Fe, 3.4; I, 0.12; Se, 0.025; Co, 0.03; thiamine, 0.05; riboflavin, 0.04; folic acid 0.4; vitamin K3, 0.2; biotine, 0.0015; vitamin A, 850000IU, Vitamin D3,175000 IU; Vitamin E 1500 IU

2.4. Carcass traits

After 49 days of fattening period a total number of thirty rabbits (fifteen male rabbits per diet), with an average live weight (1957 ±75 g) were slaughtered after 12 hours feed withdrawal. Rabbit slaughtering followed national regulations and carcasses were prepared as described by Blasco and Ouhayoun (1996). Hot carcass, skin, digestive tract were weighted and expressed as percentage of slaughter weight. Digestive tract was dissected and washed to determine the different proportions of full and empty stomach, small intestinal, caecum and colon. After 24 h chilling at +4 °C, commercial carcass, head, liver and kidneys were weighed, and lungs, esophagus, trachea, thymus and heart were recorded as a single weight (Σ Organs). Dressing percentage was also calculated and commercial carcass weight was recorded. Commercial carcass yield was calculated consequently. Carcasses were graded according to AFNOR (2004) to evaluate the adiposity (from 1, scarce, to 5, excessive). Furthermore, carcasses were cut as described by Blasco and Ouhayoun (1996). The fore part, intermediate part, hind part, scapular fat and perirenal fat were weighed and then converted to percentages of reference carcass. The ratio meat to bone was calculated after dissection of one of the legs.

2.5. Meat quality analysis

Biceps femoris (BF) and *Longissimus dorsi* (LD) pH, was measured at the level of the 5th lumbar vertebra using a pH-meter (type 330 i / SET WTW) after slaughtering (initial pH_{20mn} : pHi) and at 24 h post-mortem (ultimate pH : pHu).

Water holding capacity was estimated by measuring total water loss, which is the sum of drip and cooking loss, according to Honikel (1998) method and expressed as percentage of weight loss. Meat samples of BF and LD were weighted and placed in polyethylene bags and suspended in a refrigerator at +4°C, from the second to the seventh day of the storage period. They were weighed daily to evaluate the drip loss. Subsequently, they were cooked in water bath heated at 75°C for one hour and meat internal temperature was 70°C.

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Chemical composition (Dry matter, ash, crude protein, and crude fat) of meat leg and saddle was carried out according the AOAC (1995).

2.6. Color measurements: Meat color was measured on *Biceps femoris* (BF) and *Longissimus dorsi* (LD) (at the sixth lumbar vertebra (from the second to the seventh) and lightness (L*), redness (a*), yellowness (b*) were recorded, using a Minolta CR-401 chromameter according to CIE L*a*b* system (Hernandez and Dalle Zotte, 2010).

2.7. Sensory evaluation

A taste panel assay was carried out to evaluate meat sensory characteristics. The right leg from each of 4 carcass rabbits per diet was cut into 6 uniform pieces of boneless meat. Meat samples were cooked in an electric oven preheated to 240°C for about 40 min to an internal temperature of 80°C. They were distributed in previously coded plates. Eight trained panelists participated to the sensory evaluation. Each panelist was installed in a single cabin and received successively three plates with two hot pieces of meat in each plate. Panelists were led to observe, smell, taste and classify the pieces on different scales of increasing intensity of color, tenderness, juiciness and flavor. Water and bread were presented to each panelist so that they could change the taste of his mouth after tasting each sample.

2.8. Chemical analysis

Dry matter (DM), organic matter (OM), crude protein (CP) and extract ether (EE) were measured according AOAC (1995) procedures. Crude fiber (CF) and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were analyzed according Weende and Van Soest et al. (1991) methods, respectively, while CP was analyzed according to Kjeldahl nitrogen method. Condensed tannins in carob pods were analyzed by using the vanilline method reported by MAKKAR and BECKER (1993).

2.9. Statistical analysis

All the data were subjected to a variance analysis using the following general linear model (GLM) : $Y_{ij} = \mu + Diet_i + \mathcal{E}_{ij}$

Where, Y_{ij} is the observation of the dependent variable, μ is the overall mean, $Diet_i$ is the effect of diets (i = Control and Carob) and $\mathcal{E}_{ij}$ is the residual error.

The software SAS (SAS institute, 2003) was used to evaluate the diet's effect. The effect of carob inclusion was evaluated by least square difference (LSD) test. The level of statistical significance was set at $p < 0.05$.

3. RESULTS

3.1. Growth performance

Overall data indicated in Table 2 showed that, carob fruit did not reduce growth performance ($p>0.05$). Indeed, final LBW and ADG were 2012 g and 28.6 g/d and 1955 g and 27.5g/d, in control and carob lots, respectively. Feed intake and FCR were similar in both groups and mortality rate was significantly reduced ($p<0.05$) in carob rabbits, (14.29% vs. 2.04%). Main mortalities were observed when temperature exceeded 30°C.

Table 2: Effect of diets on growth performance

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	Control	Carob	SEM	Significance
Initial LBW (g)	609	606	2.459	ns
Final LBW (g)	2012[a]	1955[b]	12.16	*
ADG (g/day)	28.6	27.5	1.456	ns
FI (g/day)	111	112	1.550	ns
FCR (g of FI/g ADG)	3.88	4.08	0.341	ns
MR (%)	14.29[a]	2.04[b]	1.394	**

[a,b]: Least square means in the same row with different superscript letters are significantly different; SEM: Pooled standard error of the mean, ns non significant.
*P<0.05; **P<0.001;.

3.2. Carcass traits

Live body weight of the slaughtered rabbits, was similar (Table 3) and hot and cold carcass weights were higher in control group. Hot and commercial and reference carcass yields were comparable in both groups, likewise skin and the gastrointestinal tract proportions. Carob feed decreased the liver weight about (-0.26%) and no difference was detected in the full digestive organs weights (p>0.05). However, emptied of their contents, the stomach and colon were heavier in carob group (p<0.05), (Table 3).

Table 3: Effect of carob on rabbit slaughter performances, offals and digestive tract

	Control	Carob	SEM	Significance
Live body weight (g)	1981	1933	19.43	ns
Hot carcass weight (g)	1254 [a]	1221 [b]	10.07	*
Commercial carcass weight (g)	1239 [a]	1204 [b]	9.29	*
Hot carcass yield (%)	63.33	63.18	0.441	ns
Commercial carcass yield (%)	62.58	62.29	0.468	ns
Reference carcass yield (%)	52.41	52.14	0.457	ns
Skin (% body weight)	14.43	15.23	0.324	ns
Digestive tract (% body weight)	14.49	13.90	0.426	ns
Head (% commercial carcass weight)	9.80	10.03	0.245	ns
Liver (%commercial carcass weight)	3.45 [a]	3.19 [b]	0.084	*

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Kidney (%commercial carcass weight)	0.86	0.88	0.019	ns
Σ Offals^{+} (% commercial carcass weight)	1.93	1.95	0.058	ns
Stomach and intestines' proportions				
(% Digestive tract)				
Full				
Stomach	23.02	20.76	0.873	ns
Small intestine	18.50	18.91	0.746	ns
Caecum	36.39	39.22	1.332	ns
Colon	11.81	15.97	2.000	ns
Empty				
Stomach	6.10^{b}	6.81^{a}	0.185	*
Small intestine	0.95	1.00	0.034	ns
Caecum	8.85	9.59	0.357	ns
Colon	6.22^{b}	8.49^{a}	0.443	**

^{a,b} Least square means in the same row with different superscript letters are significantly different; SEM: Pooled standard error of the mean; ns non significant.
*P<0.05; **P<0.001;
$^{+}$thymus + trachea +esophagus + lungs + heart

Fore, hind and intermediate parts, revealed a similarity between both treatments (Table 4). Nevertheless, adiposity analysis showed comparable proportions of scapular and peri-renal fat (0.46% and 1.2%, respectively) between both lots. Same findings were obtained by the visual assessment, thus, the score assigned to the carcass of rabbits fed the control diet was identical to that detected in those of rabbits receiving carob regimen (2.71 and 2.79, respectively). In addition, rabbits from both treatments showed no difference in meat to bone ratios (7.58 and 7.47, respectively).

Table 4: Effect of carob on fore, intermediate and hind parts proportions, body composition and fatness (% commercial carcass yield)

	Control	Carob	SEM	Significance
Fore part	35.3	35.8	0.339	ns

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Intermediate part	26.8	26.5	0.562	ns
Hind part	37.9	37.6	0.623	ns
Meat to bone ratio of the hind leg	7.58	7.47	0.252	ns
Scapular fat	0.46	0.46	0.035	ns
Perirenal fat	1.18	1.28	0.105	ns
Adiposity^{++}	2.71	2.79	0.204	ns

^{a,b}: Least square means in the same row with different superscript letters are significantly different ($P<0.05$) ; $^{++}$: Adiposity Visual appreciation; SEM: Pooled standard error of the mean, ns non significant.
**$P<0.001$

The initial pH values (Table 5) measured on the *Biceps femoris* (BF) and *Longissimus dorsi* (LD) muscles were comparable between rabbits in both groups. Ultimate pH (pH_u) was lower than the initial pH (pH_i) of 1.5 and 1.4 points in BF and LD muscle, respectively.
The regimen did not influence meat drip, cooking and total water losses (Table 5). Indeed, these parameters, measured on the BF and LD, were similar and showed no difference between both diets, thus avoiding the presence of any bounded effect to the carob use ($p>0.05$). Moreover, lightness (L*), redness (a*) and yellowness (b*) results shown in Table 5, were not affected by carob feed inclusion.

Table 5: Effect of carob on pH and water losses

	Control	Carob	SEM	Significance
Biceps femoris (BF)				
pH_i	6.79	6.90	0.074	ns
pH_u	5.67	5.73	0.056	ns
Total water loss	20.54	17.78	1.503	ns
Drip loss	3.81	3.70	0.176	ns
Cooking loss	16.74	14.09	1.529	ns
L*	60.64	61.37	0.447	ns
a*	9.89	9.45	0.348	ns
b*	3.87	4.26	0.188	ns
Longissimus dorsi (LD)				

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pH_i	6.98	6.94	0.071	ns
pH_u	5.53	5.58	0.048	ns
Total water loss	26.31	22.24	1.696	ns
Drip loss	6.09	5.36	0.327	ns
Cooking loss	20.21	16.88	1.630	ns
L*	70.06	70.32	0.674	ns
a*	8.39	8.07	0.639	ns
b*	5.81	6.34	0.217	ns

(L*) Lightness, (a*) redness, (b*) yellowness, SEM: Pooled standard error of the mean, ns non significant

Table 6 summarized the results of the meat chemical analyzes. Although the dietary protein intake was similar for both diets, these results showed higher CP and lower crude fat contents in carob rabbit's BF (20.82 *vs* 21.47 and 7.61 vs 7.23), respectively while LD meat chemical

Table 6: Diets effects on meat chemical composition (%)

	Control	Carob	SEM	Significance
BF				
Moisture	76.13	76.03	0.213	ns
CP	20.82 ^{b}	21.47 ^{a}	0.195	**
Crude fat	7.61^{a}	7.23^{b}	0.12	*
LD				
Moisture	75.56	76.08	0.196	ns
CP	20.82	21.47	0.508	ns
Crude fat	1.72	1.69	0.15	ns

^{a,b}: Least square means in the same row with different superscript letters are significantly different (P<0.05) ; SEM: Pooled standard error of the mean, ns non significant.
*P<0.05, **P<0.001

Sensory evaluation didn't show any differences attributed to diets (Table 7) and rabbit meat in control and carob lots was tender, more or less juicy, with a fairly strong odor and intense flavor and light color.

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Table 7: Diets effects on sensorial characteristic of leg meat

	Control	Carob	SEM	Significance
Tenderness	7.15	6.36	0.366	ns
Juiciness	6.15	5.50	0.331	ns
Color	4.85	4.34	0.382	ns
Odor	5.98	6.07	0.307	ns
Flavor	5.19	4.95	0.418	ns

SEM: Pooled standard error of the mean.

4. DISCUSSION

Rabbit's growth rate wasn't influenced by the use of the carob and feed intake and FCR was not decreased by carob inclusion. In contrary, Abu Hafsa et al. (2016) reported that the increase in inclusion rate of carob pods from 0, 2.5; 5 to 10% significantly decreased feed intake, while they recorded, among diets containing the best value of feed conversion ratio in the diet containing 5% carob pods. However, several authors studying the effect of a low digestible fiber source incorporating (ADF and ADL) into growing rabbit's diets, founded a significant decrease in ADGg (Alvarez et al., 2007 and Nicodemus et al. (2002). Hence, it appears that the carob contains compounds that compensated the negative effect of lignocellulose on rabbit growth. Furthermore, our results revealed that carob diet reduced significantly mortality rate. This important finding is probably due to the positive effects of secondary components such as tannins. In fact, Kermauner and Laurenčič (2008) mentioned that tannins limit peristaltic activity in digestive disorders and can protect intestinal mucosa against oxidative damage and pathogens preventing diarrhea, the principal cause of mortality in rabbit. Moreover, carob with its antioxidant nutrients may attenuate substantially heat stress effects in growing rabbits in Tunisian summer conditions. Kamal et al. (2013) reported that carob powder is a rich source of soluble dietary fiber, minerals (Fe, Ca, Na, K, P and S) and vitamins (E, D, C, Niacin, B6 and folic acid). It contains in addition eleven phenolic compounds essentially Pyrogallol, catechol, chlorogenic and protocatechuic recorded the highest values. The same authors confirmed that carob powder is acclaimed ingredient with a marked nutritional value due to its high dietary fiber and phenol compounds. Sebai et al. (2013) demonstrated that Tunisian carob pods' extracts contained high contents of phenolic compounds. They reported also the aqueous extract showed antioxidant capacity and properties in rats by decreasing the tissues lipid peroxidation and hydrogen peroxide contents.

Our findings showed that carob decreased hot and commercial carcass ($p<0.05$), however both carcass yields were similar. Abu Hafsa et al. (2017) detected that 10% of feed inclusion of carob decreased the slaughter weight and carcass dressing percentage weight. Empty stomach and colon and liver proportions were higher in carob rabbits. According to Dalle-Zotte (2002) and Combes and Lebas (2003), feed inclusion of carob in growing rabbit diets has almost no effect on carcass composition, with the exception of a difference in the relative weights of the liver and

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hind part. The gastrointestinal tract proportion is comparable to that of Alvarez et al. (2007), but opposes the result of Nicodemus et al. (2002). Gruendel et al. (2007) founded that the ingestion of carob has the advantage of reducing the postprandial glucose level by storage in the liver, thus increasing the weight of this organ. Liu et al. (2009) reported that with the increase of tannins levels, the ratio (liver weight/live body weight) × 100, decreased. However, Mohamed et al. (2001) suggested that higher levels of tannins might have a toxic effect. They reported an increase in the liver weight in rabbits fed high-tannin, but not in those fed low-tannin. Moreover, tannins' content in carob may enhance the lipid metabolism by promoting their use by oxidation (Gruendel *et al.*, 2007), and contribute to the reduction of adiposity. Similarly, Kotrotsios et al. (2012) using carob in the pigs' diet did not show any effect on carcass adiposity. Carob feed affected empty stomach and colon weights, since their lignocellulose and lignin contents are different, and consequently retention time of feed particles in the different digestive tract segments would be variable. Moreover, studies on the influence of environmental parameters on the quality of the carcass and meat focus mainly on the effects of temperature. At temperatures high (30 °C) or during summer, the decrease in feed intake and growth performance of animals, induce a carcass low weight but with a better yield due to the decrease of the relative weight of the skin and the tube digestive tract.

Carob feed did not affect the initial and ultimate pH. Our results corroborate with those found by Marguenda et al. (2008) in meat of rabbits receiving a feed containing lower digestible fiber. These results are also, in agreement with those of Liu et al. (2009), who found that chestnut tannins didn't affect pH24h value. This was also confirmed by Hernandez and Dalle-Zotte (2010), who reported that feeding doesn't affect either the initial pH or the ultimate pH. Dal Bosco et al. (2014) detected the same tendency for the pH evolution; it's significantly increased with time. Cabanes et al. (1996) reported that pH variations depend on two opposite events: the hydrolysis of proteins, with NH_3 release, and the hydrolysis of lipids with release of fatty acid. Hernandez and Dalle Zotte (2010) and Liu et al. (2009) did not observe any diet effect on water holding capacity in rabbit meat. In contrast, Dal Bosco *et al.*, (2014) detected a significant drip loss reduction in Thyme group. We noted that LD is characterized by a high lightness and redness indexes (L* = 70 and a* = 8), respectively associated probably to myoglobin content. Hernandez and Dalle-Zotte (2010) reported lower, color indexes values in LD muscle (L*: 56 - 60, a*: 2.06 - 3.04, b*: 4 - 5). Color parameters (L*, a*, b*) of LD muscle were not affected by carob feed inclusion at 20%. Our results corroborate with those of Liu et al. (2009). However, Dal Bosco *et al.*, (2014) reported that the dietary spirulina and thyme supplementation had a significant effect on redness and yellowness evolution of LD muscle. Dal Bosco et al. (2012) reported that the chemical composition of *longissimus lumborum* muscle was not affected by the diet. In addition, our sensory evaluation results of color and juiciness demonstrated that carob didn't have any incidence on sensory quality of rabbit meat. Dalle-Zotte (2002) mentioned that the traditional consumer considered rabbit meat to have positive sensory properties: it is tender, lean and flavored.

5. CONCLUSION

It is concluded that carob feed inclusion at 20% in fattening rabbit diet, had no negative incidence on growth performance and improved significantly animal viability in summer conditions in Tunisia. Furthermore, carcass traits were not globally affected by the diets. Carob

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diet seems to reduce adiposity in carcass and no differences were detected by the panelists in terms of the sensory meat quality. However, by incorporating this resource, we must put into consideration the nutritional requirements of rabbits, and especially to keep a balanced rate of fiber, especially ADF and ADL. Thus, carob pods are a local feed resource available in Tunisia that may represent a good alternative to imported raw materials, in helping to reduce the feed cost for Tunisian rabbit farmers.

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