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Impact of Carob Supplementation on Sensory Meat Quality of Rabbits

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ABSTRACT
The objective of this study was to investigate the effects of including carob in rabbit diets on meat quality. At 35 d of age, 68 local Algerian rabbits were weaned and randomly divided into two groups, each containing 34 rabbits. Two experimental diets were used: a control diet designed to meet the nutritional needs of fattening rabbits, and the "CR15" diet, which included 15% carob, replacing barley in the control diet. Sensory analysis revealed that the meat from carob-fed rabbits exhibited greater tenderness (4.95), juiciness (4.91), and flavor (5.0) compared to the control group. The study concluded that adding 15% carob to the diet enhances the organoleptic qualities of the meat and increases the overall preference for cooked meat, particularly roasted meat. Thus, carob supplementation can be a valuable strategy for improving carcass traits and meat quality.

Keywords: Ceratoniasiliqua; dietary effects; flavor; local rabbit; organoleptic analysis.

INTRODUCTION

Meat is a valuable and essential component of every society's diet [1]. According to official data, Algerians consume the least amount of meat in the Maghreb [2,3] and the use of rabbit *(Oryctolagus cuniculus*) meat is not as deeply rooted in culinary traditions as other meats that are more commonly consumed, such as sheep and chicken [4].
To meet consumer demands and manage the market during peak periods, such as Ramadan and other religious holidays[5], rabbits offer a viable option for providing high-quality animal protein to growing populations in developing countries [6]. Rabbits possess several desirable characteristics, including low production costs, small body size, short generation intervals, high fecundity, rapid growth rates, genetic diversity, the use of agricultural by-products for feed, and adaptability[6].
Consumers prefer rabbit meat for its high nutritional value[7,8.9,10]. Rabbit meat has a moderate calorie content and low sodium levels while being rich in potassium, magnesium, phosphorus, selenium, and B vitamins (it is the highest source of vitamin B12) [11,12]. Compared to other meats, rabbit meat has lower fat and cholesterol content, high protein levels with essential amino acids, and excellent digestibility [13].
Thus, to meet the animal protein needs of a growing population, Algeria must give greater importance to this livestock sector, which remains somewhat marginalized, with an estimated production of 8,468 tons in 2018 [14]. The goal is to supply the local market with nutritious meat options and address the shortage of red meat in the average consumer's diet. Rabbit farming can help alleviate the deficit in animal protein.
On the other hand, since September 2006, the price of agricultural raw materials has increased dramatically. By 2007, these prices had risen by a factor of 1.5 to 2. This situation led to a 25-30% increase in the price of rabbit feed [15]. However, Algeria's rabbit production industry faces challenges due to the high cost of imported raw materials.
The high cost of these materials should encourage farmers to use local, more affordable resources. In this context, indigenous raw materials like carob (*Ceratonia siliqua*) are viable alternatives to imported components. Encouraging a circular economy and reducing waste that could pollute the environment, using surplus carob or fruits unsuitable for human consumption as livestock feed presents an economically feasible option [16]. Estevez (2021) [17] suggests that utilizing natural sources of nutrients and bioactive compounds can be a cost-effective and efficient means to enhance meat quality.
Thus, using local feed resources could be a viable option for replacing imported raw materials in rabbit diets. Consequently, we focused on carob pods. The carob tree *(Ceratonia siliqua L.)*, a Mediterranean-origin fruit, grows wild but is also cultivated in many parts of the world, such as regions in the United States, Latin America, and Australia

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[18,19,20]. Carob pulp contains between 30 and 60% sugar, with sucrose accounting for 65-75%, fructose for 15%, and glucose for 25%. It is rich in fiber (about 8%) and carbohydrates (40%) and also includes 3% protein and 1% fat. Additionally, carob pulp provides vitamins and minerals [21,22,23,24].

For centuries, the carob tree has been used as a food source for both animals and humans in the Mediterranean region. Today, it is gaining significant interest internationally and is widely used in the food industry and pharmacology. Algeria ranks eighth among carob producers globally, with a production of 49,693 tons (Food and Agriculture Organization Statistics [25]. This tree is of considerable economic importance and generates various products (pulp, seeds, gum) that are traded extensively in Europe.

From a scientific perspective, the limited studies on incorporating carob into animal feed have primarily focused on fattening rations or seed extracts in rabbit farming [26]. However, there is a notable lack of research focused on consumers' preferences or motivations regarding the quality of rabbit meat. This study aims to initiate research into the impact of carob on rabbit meat quality and assess how cooking influences its sensory attributes. Furthermore, it seeks to encourage Algerians to consume more rabbit meat and adapt their culinary habits compared to their North African counterparts.

This research also aims to reduce the cost of animal feed in rabbit farming while maintaining high-quality meat standards. Our study investigates the effect of carob pods on carcass characteristics and sensory qualities of rabbit meat.

MATERIALS AND METHODS

The experimental site, animals, and management

The study was conducted at the experimental rabbitry in Algeria. Sixty-eight local Algerian rabbits (Oryctolagus cuniculus) , weaned at 35 d old with an average weight of 662.75 ± 10 g, were randomly divided into two groups (34 rabbits per group). Two different precision electronic scales were used for weighing the rabbits and the feed, with capacities of 15 kg and 1.8 kg, respectively (Model SF-400,China).Each rabbit was housed individually in flat-deck galvanized cages (Algeria) measuring 0.34 m², elevated 90 cm above the concrete floor, and maintained at a temperature of 21 ± 3 °C. All animals originated from the same litters of 7–8 kits at weaning. Medication was not administered through feed, water, or injection during the study.

The experimental diet

The rabbits were fed a commercial pelleted meal formulated with essential nutrients, including a balanced ratio of protein (approximately 16-18%), fiber (around 20-25%), and vitamins (vitamins A, D, and E), with a gross energy content of approximately 2400 Kcal/kg, designed to meet the nutritional requirements for growing rabbits. Additionally, they were provided with one of two experimental diets ad libitum for 12 weeks. Carob was sourced from Batna Province, located in eastern Algeria. The carob pods were manually crushed and milled into fine particles of 2-3 mm using a traditional wooden grinder (Algeria) for inclusion in the experimental diets. The control diet (Group C) was locally formulated and consisted of seven indigenous ingredients: barley (*Hordeumvulgare*), corn (*Zea mays*), alfalfa flour (*Medicago sativa*), wheat bran (*Triticum*), soy (*Glycine max*), and a supplement containing minerals and vitamins. This diet was presented in granular form, with a diameter of 2.5 mm and lengths ranging from 4 to 20 mm (see TABLE I). The other diet (CR15) was formulated by substituting barley with 15% carob meal. The proximate composition of the carob is shown in TABLE I [27]. The chemical composition of the carob used was consistent with previous reports due to its Mediterranean origin. Water was given ad libitum via nipple drinkers.

TABLE I: Chemical composition (% DM) of the experimental diets

	Granulated feed	**Carob**
DM (%)	89.58	88.7
Crude protein	16.3	4.2
Ether extract	4.58	0.4
NDF	33.2	29.8
ADF	18.8	23.1
ADL	4.68	12.8
FAT	0.5-1	2-5
Total nitrogen(%)	19.61	6.38
Total Minerals (%)	7.41	2.76
Cellulose fiber (%)	14.43	12
Gross energy (Kcal/kg)	2403	2147

DM, Dry matter; NDF,neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin.

Data collection

Data were collected over 8 weeks. The rabbits' weights were measured at the start of the experiment and then weekly. Total weight gain was calculated by subtracting the initial weight from the final weight. At the end of the experimental

period, the rabbits were manually slaughtered according to the Muslim rite in an experimental slaughterhouse to assess carcass traits.

Carcass traits

The slaughtering and carcass dissection procedures were carried out following the World Rabbit Science Association guidelines [28]. After slaughter, the rabbits were bled, skinned, and the digestive and urogenital organs were removed before weighing. The weights of the heart, liver, kidneys, and lungs were recorded and expressed as a percentage of live weight (%l.w).Meat samples were taken one hour after slaughter, covered in aluminum foil, and refrigerated in a an LG refrigerator (LG ,smart inverter-3000,Korea) refrigerated at 4°Cfor 24 hours.

Evaluation of the sensory qualities of rabbit meat

The meat quality was assessed by analyzing parameters through a sensory evaluation test. Sensory testing remains the most widely used method for scoring the organoleptic properties of meat [29]. The main parameters evaluated in this analysis were color, flavor, tenderness, and juiciness of the meat.

Meat Samples

For sensory evaluation, the right leg from each of the ten carcasses per diet, which is the most popular cut among consumers, was used to assess the impact of carob on the sensory qualities of rabbit meat. Samples of rabbit meat (200 g) from the thigh muscle were taken from all groups. In the first session, the meat sample was roasted in an electric oven (LG,Model MC-7880SL/00, Korea) at 220°C for 35 minutes, reaching an internal temperature of 80°C, and was prepared without any added salt, spices, or condiments. In the second session, the samples were cooked using three methods:
Boiling: Meat pieces were immersed in an inox water bath (Condor,TM professionnal Algeria)at (100 ± 1 °C for 8 minutes.
Frying: Meat pieces were immersed in sunflower (*Helianthus annuus*) oil at 175 °C for 3 minutes.
Roasting: Meat pieces were placed in aluminum pans and put in an electric oven preheated to 200 °C for 15 minutes.
The meat samples were cut into 6 small pieces (2 cm^3/piece) following the protocol of Kim *et al.*[30] (2009) and distributed on pre-labeled small white plates for presentation to the panel of judges and scorers.

Panelists and sessions

Twenty-four panelists (15 men and 9 women, aged 21–52 years) participated in this study. They were selected based on their regular consumption of rabbit meat and their familiarity with sensory testing. Each panelist participated in two sessions. The first session focused on evaluating the sensory characteristics of the meat itself, while the second session investigated the impact of different cooking methods on carob-supplemented rabbit meat.
During the two sessions, panelists received four plates, each containing two hot meat pieces: one control sample (without carob) and one CR15 sample (with 15% carob). In the first session, they examined only one plate. In the second session, they received three plates, each representing a different cooking method: boiling, frying, or roasting. Panelists were invited to rinse their mouths with water between each sample.

Sensory attributes and preferences

Panelists observed and assessed the appearance, smell, taste, and texture of the meat samples using custom scales designed to measure the intensity of color, tenderness, juiciness, flavor, and overall acceptability. They then ranked these attributes based on their individual preferences, creating an order or hierarchy for each meat sample and cooking method. These ranked attributes represent an ordered scale of characteristics, evaluated based on subjective factors such as preference and perception.
Panelists used the custom scales mentioned above to evaluate the meat samples, reflecting the increasing intensity of each attribute. They rated their overall liking using a 5-point hedonic scale (1: dislike extremely; 5: like extremely), as described by Mahmoudi *et al*. [16].
Each panelist was asked to score the tenderness of each meat on a 5-point hedonic scale (5: like extremely tender; 4: very tender; 3: moderately tender; 2: very tough; 1: dislike extremely). They also rated juiciness, flavor, color, and overall palatability on a similar 5-point scale. Additionally, during the second session, panelists used the same scale to rank the three cooked samples based on their overall liking, from most preferred to least preferred.

Statistical analysis

All gathered data and sample evaluation values were first imported into Microsoft Excel 2007 and then transferred to Minitab for analysis. Quantitative performance parameters and sensory evaluations from different groups were analyzed using the t-test and analysis of variance (ANOVA). A *p*-value of less than 0.05 was considered the threshold for statistical significance. When the p-value was less than 0.05, differences between the parameters were considered significant, and when it was less than 0.01, they were considered highly significant.

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RESULTS AND DISCUSSION

Effect on abdominal fat

In this study, rabbits fed a carob-supplemented diet showed a reduction in the relative weight of abdominal fat compared to the control group (40% reduction; 5g vs. 3g). This result aligns with previous research by Mahmoudi *et al.* [16]and Sour *et al.* [31], who observed a similar decrease in adipose tissue weight in rats fed a carob pulp diet. The reduction is attributed to phenolic compounds and fiber found in carob, which may inhibit the formation of fat cells (adipocytes) and reduce fat accumulation. Carob supplementation in the diet potentially reduces abdominal fat without affecting overall health.

Sensory evaluation

There is no published research related to the sensory evaluation of meat derived from rabbits fed carob, which makes the present study innovative. TABLE II displays the findings of the impact of adding carob to the rabbits' diet on their sensory assessment.

TABLE II: Effect of Carob on sensory characteristics of rabbit meat

	Control diet	**CR15**	**SEM**	***p***
Color	3.50	3.95	0.49	NS
Flavor	3.37^{b}	5.00^{a}	0.51	<0.05
Juiciness	3.79	4.91	0.58	NS
Tenderness	3.87	5.00	0.67	NS
n = 24;^{a,b}, means in the same row bearing different superscripts differ significantly (P < 0.05); NS, Not significant. CR15?? CR15 (experimental group) refers to the diet formulated by substituting barley with 15% carob meal.				

The sensory test revealed that rabbit meat from the experimental group (CR15) exhibited a significantly stronger flavor compared to the control group (P < 0.05). More than half of the panelists gave higher scores for flavor (5.00 vs. 3.37), tenderness (5.00 vs. 3.87), and juiciness (4.91 vs. 3.79) in the meat from the carob-fed group. However, the color scores were nearly identical between the two groups (3.95 vs. 3.50), with no statistically significant differences.

The enhanced flavor, tenderness, and juiciness observed in the CR15 group may be attributed to the higher sugar content in carob pulp powder, which can influence the sensory qualities of meat. This aligns with findings from studies on chicken meat, suggesting that variations in meat tenderness and juiciness may be related to changes in fatty acid composition [32]. Furthermore, Horsted *et al.*[33] reported that flavor and aroma significantly influence consumer satisfaction with broiler breast meat, which may also apply to rabbit meat in this study.
These findings are consistent with previous research, indicating that diet plays a crucial role in determining the organoleptic properties of meat [34,35]. Additionally,Mahmoudi *et al.*[16]highlighted that carob supplementation positively affects the intestinal microbiota, which may further contribute to improved meat quality.
When comparing different cooking methods (boiling, roasting, and frying) on the organoleptic properties of rabbit meat (TABLE III), it was noted that boiling led to increased tenderness in the carob-supplemented group (tenderness score of 7.08), while frying significantly reduced tenderness (2.18) compared to the control diet (5.00 and 4.16, respectively).

TABLE III: Effect of Carob on cooking procedures

	Control diet			CR15			p	RMSE	RCD(%)
	Boiled	Roasted	Fried	Boiled	Roasted	Fried			
Color	9.16	7.5	7.91	5.41	4.16	3.75	NS	3.76	27
Flavor	6.25	6.66	6.66	7.91	8.03	8.33	NS	1.57	63
Juisness	3.75	5.41	2.91	3.75	7.08	5.41	NS	1.94	52
Tenderness	5.00	4.16	4.16	7.08	7.91	5.00	NS	2.52	40
Delicious	5.00^{a}	7.5^{b}	7.5^{c}	5.00^{b}	9.58^{a}	8.33^{c}	<0.05	0.96	104

n = 24; ^{a,b,} means with distinct superscripts in the same row show a significant difference *(*P< 0.05); NS stands for not significant. CR15 (experimental group) refers to the diet formulated by substituting barley with 15% carob meal.

The sensory analysis revealed that roasted rabbit meat from the carob-fed group showed higher scores for juiciness and tenderness compared to other cooking methods and the control diet. The deliciousness score was particularly higher for both fried and roasted meat, with scores of 9.58 and 8.33, respectively (TABLE III).
The cooking methods did not significantly (P>0.05) affect the overall eating quality of the rabbit meat. However, within the experimental group (CR15), roasted and fried meat received the highest rankings for tenderness, juiciness, and flavor compared to other methods. These findings are consistent with others study [36], who reported that roasting is the preferred cooking method due to its ability to improve consumer acceptance and provide health benefits.

Although the inclusion of carob in the diet did not significantly alter the sensory characteristics of the rabbit meat, it seems to have enhanced the meat's organoleptic qualities, especially in terms of flavor and tenderness. However, the sensory evaluation revealed no major differences between the control and carob-fed groups for characteristics like color and overall acceptability. Carob gave the rabbit meat a stronger organoleptic character.
These results are in line with previous studies [37], who reported that the sensory quality of rabbit meat is influenced by the diet without negatively affecting color or juiciness. The non-significant differences (P> 0.05) observed among treatment groups suggest that the inclusion of carob has potential but might require larger sample sizes or more controlled experimental conditions to fully demonstrate its benefits.
The sensory analysis results indicate that the meat of local rabbits fed carob is very tender, juicy, and has a characteristic flavor, compared to that of the control rabbit. An incorporation rate of 15 percent of carob may give the meat better sensory quality and confer more organoleptic qualities. In conclusion, feeding local rabbits with a 15% carob-supplemented diet improved the flavor, tenderness, and juiciness of the meat. This dietary inclusion could be a useful marketing strategy to encourage Algerian consumers to incorporate more rabbit meat into their culinary habits.

CONCLUSION

This study demonstrated that incorporating 15% carob into the diet of weaned rabbits did not negatively impact the quality of their meat or carcass characteristics. The rabbit meat from the carob-fed group was tender, juicy, moderately light in color, and had a more intense flavor, with a higher preference for roasted meat. Carob supplementation may enhance both rabbit productivity and meat quality, providing significant nutritional benefits for both farmers and consumers. However, future studies are needed to validate these findings by testing varying levels of carob inclusion under more controlled conditions and with a larger sample size for comparison.

Ethics approval

The study was carried out in accordance with the recommendations of the Guide for the Care and Use of Laboratory Animals and in accordance with the ethical guidelines approved by the Institutional Animal Care Committee of the National Administration of the Algerian Higher Education and Scientific Research (Ethical approval number: 98-11, Law of August 22, 1998)

Conflict of interest

The authors declare no conflict of interest.

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