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EFFECTS OF SUPPLEMENTING PISTACHIO SKINS IN THE DIET ON GROWTH PERFORMANCE AND THE FATTY ACID PROFILE OF *BICEPS FEMORIS* AND *LONGISSIMUS LUMBORUM* MUSCLES IN RABBITS

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Abstract: Pistachios, a delicacy food product produced mostly in Sicily, generate significant amounts of skins during processing. This by-product has been incorporated in growing/finishing rabbit diet formulations. Hence, the aim of this study was to investigate the effects of a 6% pistachio skin inclusion in rabbit grower/finisher diets on the meat characteristics. One hundred and fifty healthy Martini rabbits (male and female) were weaned at 30 d of age and body weight (IBW) of 0.82±0.05 kg. The animals were assigned to one of the two treatment groups to be homogeneous for weight and sex. Diets were as follows: (1) a treatment diet (TRMT) with a 6% incorporation of pistachio skin meal, and (2) a control diet (CTRL) without the integration of pistachio skin meal. During the experimental period (from 30 to 63 d of age), rabbits were weighed individually on day 30, day 42 and day 63 of the trial. Weight gain, daily feed intake and feed conversion ratio were calculated. The loin and hind leg were carefully deboned and the *Biceps femoris* (BF) and *Longissimus lumborum* (LL) muscles were minced and homogenised. The treatment group fed a diet with 6% pistachio skins showed no adverse effects on the growth performance or carcass characteristics and did not trigger any physiological or clinical changes or show deleterious effects on the rabbits. Overall, while the total fat quantity did not register as significant in any of the muscles from either diet, significance was recorded with regard to the quality of the fatty acids profile between the two diets and between both muscles. The analysis of the BF and LL muscles of the TRMT group showed a significant increase in monounsaturated fatty acids (3.2, and 3.0%, P=0.008 and 0.041, respectively) and in the polyunsaturated fatty acids groups (4.8 and 3.8%, P=0.032 and 0.023, respectively), and a decrease in the saturated fatty acids group (–7.2 and –6.1%, P=0.014 and 0.020, respectively) compared with the CTRL group. In particular, both linoleic and α linolenic fatty acids registered a significant increase in the BF muscle, while only the linoleic acid registered a significant increase in the LL muscle of TRMT compared with the CTRL group (P<0.05). Although rabbit meat offers excellent nutritional and dietetic properties in itself, this study confirms that it can be further enhanced to be considered as functional through diet manipulations.

Key Words: pistachio skin, rabbits, functional foods, fatty acids, *Biceps femoris*, *Longissimus lumborum*.

INTRODUCTION

The European Union is currently updating its legislation on waste management to promote a shift to a more sustainable model known as the circular economy (Chioatto and Sospiro, 2023) with the intention of reducing waste to a minimum through reuse and recycling. This approach is expected to have significant positive environmental repercussions, especially in reducing pressure on landfills and thereby contributing towards an increase in sustainability. Over the

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last few years, significant interest has been shown in the use of several agricultural by-products (Motta Ferreira *et al.*, 1996; Oliveira *et al.*, 2008; De Blas *et al.*, 2018; Dabbou *et al.*, 2019; Arbouche *et al.*, 2021) in rabbit feed formulations. In the case of Sicily, the by-products from pistachio fruit processing may represent a potential new feed ingredient. To date, the incorporation of this novel raw material has not yet been tested on rabbit, although its use in ruminant diets is well documented in the literature (Morteza *et al.*, 2014; SoltaniNezhad *et al.*, 2016).

Pistachio (*Pistacia vera* L.), a member of the Anacardiaceae family, is native to western Asia and Asia Minor and was introduced into Italy in 30 A.D. (Minà Palumbo, 1882) and later into Sicily. Currently, 90% (approximately 4.500 hectares) of the total Italian area under pistachio cultivation is found in the eastern part of Sicily (Western slopes of Mount Etna volcano), mainly concentrated within the districts of Bronte and Adrano, both suburbs of the Province of Catania. Sicily is the only Italian territory that has two protected designations of origin (PDO): one for Bronte and recently Raffadali. The estimated production from these two PDOs was approximately 2500 tonnes for 2021.

The pistachio fruit can be classified as a semidry drupe containing a single edible seed (kernel), encased by a thin, soft coat (testa), enclosed by a lignified shell (endocarp), which is surrounded by a thick hull (mesocarp and epicarp). The industrial processing of pistachios consists of the removal of the pistachio's woody pericarp to produce shelled nuts and the removal of the thin film that wraps the cotyledons to produce peeled nuts before the drying phase. Processing generates a huge amount of pistachio skins that is currently managed as waste and as a consequence has to absorb the relevant cost (Asciuto *et al.*, 2022) associated with their disposal. Hence, the generated residual waste by-products need to be disposed of. For this purpose, the woody pericarp is used as biomass and as a renewable energy source to produce "Green Energy", while the skins are removed from the plant at a cost that is absorbed by the production chain.

Pistachio skins are rich in fibre and a good source of protein, polyphenols and antioxidants, as well as a good source of vitamin E, essential minerals and vitamins (Arjeh *et al.*, 2020). Since pistachio skins have a low economic value, they are convenient for inclusion with animal feeding formulation, thereby lowering the price of feed.

To the best of our knowledge, no studies have so far been conducted to evaluate the effects of integrating pistachio skins into the diet formulations of growing/finishing rabbits. In this context, the present study aimed to investigate the effects of a 6% pistachio skin inclusion in rabbit grower/finisher diets on the meat characteristics of growing-finishing rabbits.

MATERIALS AND METHODS

All procedures used in this study followed the European guidelines for the care and use of animals in research (Directive 2010/63/EU). The study received institutional approval from Regione Siciliana, Assessorato Regionale Delle Attività Produttive, Dipartimento regionale delle Attività Produttive, Programma Operativo Regionale FESR 2007/2013", Asse IV, Obiettivo specifico 4.1, Obiettivo Operativo 4.1.1 del PO FESR 2007/2013, CUP G97B15000140006.

Pistachio skins

The pistachio skins (PS) were supplied in bulk by Antichi Sapori dell'Etna srl (Bronte, Ct, Italy). They were dried in a fan forced oven at 40°C and subsequently ground through a hammer mill. The resulting pistachio skin meal was filled into 1000 kg jumbo-bags and transported to Mangimi Leone industry (Catania, Italy) feed mill. The computerised feed formulation program suggested a 6% incorporation as being the most practical. Once formulated and mixed, the feed was processed into pelleted growing/finishing rabbit feed.

Animals and experimental design

One hundred and fifty healthy Martini rabbits (male and female) were weaned at 30 d of age and body weight (IBW) of 0.82±0.05 kg. The animals were assigned to one of the two treatment groups to be homogeneous for weight and sex. Diets were formulated according to in-house standards of Mangimi Leone for growing rabbits. Diets were as follows: (1) a treatment diet (TRMT) with a 6% incorporation of pistachio skin meal, and (2) a control diet (CTRL) without the integration of pistachio skin meal. The list of raw ingredients and the chemical composition of the two diets are shown in Table 1. Chemical analysis of the two pelleted diets as well as that of pistachio skin meal followed

Table 1: Formulation and analytical data of the diets.

Ingredient, % as fed	CTRL	TRMT	Pistachio skin
Alfalfa meal dehydrated	45.0	42.5	
Sunflower meal partially dehulled	22.5	21.5	
Wheat middlings	15.2	13.3	
Pistachio skin meal	0	6	
Beet pulp dehydrated	5.6	5.5	
Cane molasses	5.3	4.8	
Carob pulp	3.8	3.8	
Calcium carbonate	1	1	
Sodium chloride	0.5	0.5	
Vitamins and minerals*	1	1	
Chemical composition			
Moisture	10.6	8.9	9.3
Starch, % of DM	14.4	11.9	
Crude protein, % of DM	17.5	18.2	18.16
Fat, % of DM	3.0	4.5	29.68
Crude fibre, % of DM	17.1	17.3	31.46
Ash, % of DM	8.0	8.3	4.56
Digestible energy (Mcal/kg of DM)**	2.5	2.5	
Digestible energy (MJ/kg)**	10.3	10.3	

CTRL: control diet; TRMT treatment diet; DM: dry matter.
*Pelleted; the concentrate provided the following per kg: vitamin A: 15000 IU; vitamin D3: 2000 IU; vitamin E: 50 mg; vitamin B1: 5 mg; vitamin B2: 6 mg; vitamin B6: 3 mg; vitamin B12: 0.025 mg; pantothenic acid: 20 mg; niacin: 60 mg; folic acid: 1 mg.
**Calculated (INRA, 2002).

the standard AOAC methods, and the fatty acid methyl esters (FAME) were determined with GC–FID, following the procedure described by Liotta *et al*. (2015) and summarised in Table 2.

Each treatment group consisted of 75 rabbits individually housed in 2-tier Californian style growing/finishing wire cages (20×35×30 cm) for the entire duration of the trial period. Throughout the experimental periods, the animals had *ad libitum* access to water and feed. The rabbits were kept in a barn on a commercial farm with an average internal temperature of 20°C and a 65% relative humidity (controlled temperature and humidity) throughout the testing period. No animals had to be culled from the trial due to morbidity.

Table 2: Fatty acid composition of the diets used to feed rabbit: Ctrl and Exp integrated with 6% pistachio skin.

	CTRL	TRMT
Fatty acid classes		
SFA	19.85	16.45
MUFA	23.96	33.66
PUFA	56.19	49.90
n-3 PUFA	3.80	3.61
n-6 PUFA	52.30	46.29
USFA:SFA ratio	4.04	5.08
PUFA:SFA ratio	2.83	3.03

The concentration of fatty acid was expressed as g/100 g, considering 100 g the sum of the areas of all FAME identified.
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids. USFA/SFA: unsaturated fatty acids/saturated fatty acids ratio. PUFA:SFA ratio polyunsaturated fatty acids/saturated fatty acids ratio.
CTRL: control diet; TRMT treatment diet.

Growth performance measurements

During the experimental period (from 30 to 63 d of age), daily feed intake per cage was measured and orts from each cage were collected daily and weighed. Rabbits were weighed individually on day 30, day 42 and day 63 of the trial. The average weight gain and daily feed intake were calculated.

Slaughtering, sampling and post-slaughter analysis

At the end of the trial, at day 63 of age, all rabbits were transported to a public abattoir and processed following the guidelines set by the European Community (1099/2099/EC 2009). Following proper bleeding, the carcasses were dressed by removing the skin, distal portions of legs, distal part of the tail, all the organs located within the thorax and neck area (lungs, oesophagus, trachea, thymus, heart), genital organs, urinary bladder and gastrointestinal tract, liver and kidneys. Hot carcass weight (HCW) did not include blood, skin, distal parts of the tail, fore and hind legs, gastrointestinal and urogenital tracts. The dressed carcasses were left at +4°C in a ventilated room for 24 h as indicated by Blasco *et al.* (1993). The chilled carcasses were weighted and the carcass was separated into the various joints.

The loin and hind leg were carefully deboned and the BF and LL muscles were minced and homogenised. Samples for analysis were vacuum packaged and kept at −18°C until assayed. The butchering and carcass dissection procedures followed the recommendations described by EFSA (2020). These cuts are usually considered to be the most representative cuts of the carcass and also the most valuable ones due to their high protein content and low collagen amount (Pla *et al.*, 2004; Daszkiewicz *et al.*, 2011; Kowalska *et al.*, 2014).

Laboratory analysis of muscle samples

Studies that focus on the effects of feeding regimen or supplementation on the fatty acid profile of rabbit meat usually analyse the fatty acid composition of two main muscles: *Longissimus lumborum* and *Biceps femoris*. Each of the BF and LL muscle samples was analysed in triplicate. To determine their chemical composition, AOAC methodologies for moisture (no. 950.46 2010), crude protein (no. 981.10 1983) and ash (no. 920.153 and no. 923.03) were performed. Total lipids were extracted from both the BF and LL muscles (intramuscular fat, IMF) using the ISTISAN method (1996/34 met. B page 41) with acid hydrolysis. The chromatographic analysis was performed using 15 mg of lipids that were extracted using a solution of chloroform/methanol (2:1, v/v) from each muscle sample (Folch *et al.*, 1957). Fatty acid methyl esters were prepared (Christie, 1993) using a solution of sulphuric acid/methanol (1:9, v/v) and subjected to an HRGC analysis (Liotta *et al.*, 2015) with an FID detector (Agilent Technologies 6890 N, Palo Alto, CA, USA) equipped with an Omegawax 250 column (Supelco, Bellefonte, PA, USA; 30 m×0.25 mm i.d., 0.25 µm film thickness). The IMF samples were analysed in triplicate by GC following the standard laboratory protocol and the results are reported as the mean values of the three runs.

The proportion of each fatty acid was expressed as a percentage, considering 100% as the total sum of the identified FAMEs.

Table 3: Effect on growth and carcass performance of rabbits fed Ctrl or Exp diet integrated with 6% of pistachio skin.

	CTRL	TRMT	SEM	*P*-values
No. animals	75	75		
Body weight, kg				
Initial (30 d)	0.858	0.844	0.356	0.345
Intermediate (42 d)	1.250	1.231	0.032	0.123
Final (63 d)	1.950	1.915	0.019	0.253
Average daily gain (kg/d)	0.034	0.033	0.110	0.115
Carcass weight (kg)	1.092	1.088	0.013	0.098

CTRL: control diet; TRMT treatment diet; SEM: standard error of least square means.

Table 4: Effect on chemical composition of *Biceps femoris* and *Longissimus lumborum* muscles of rabbits fed Ctrl or Exp diet integrated with 6% of pistachio skin.

Muscle	Diet	No.	Moisture, %	Protein, %	Fat, %	Ash, %
Biceps femoris	CTRL	75	75.5	21.4	2.0	1.1
	TRMT	75	74.9	21.6	2.4	1.1
SEM			0.55	0.47	0.19	0.08
P-values			0.201	0.364	0.104	0.389
Longissimus lumborum	CTRL	75	75.0	22.4	1.4	1.2
	TRMT	75	74.9	22.6	1.3	1.1
SEM			0.81	0.46	0.16	0.09
P-values			0.275	0.188	0.325	0.155

CTRL: control diet; TRMT treatment diet; SEM: standard error of least square means.

Statistical analysis

The meat quality data were submitted to a mixed model analysis by SAS (version 9.3; SAS Inst. Inc., Cary, NC), which included the effect of the diet (CTRL, TRMT) as fixed factor and the pen as a random factor. Least square means (LSM) and standard error of least square means (SEM) were calculated. Comparisons between LS means were performed using the Tukey test. Differences were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Feed ingredients with high fat content have a negative effect on some aspects of pellet quality, as the lubricant effect increases the rate of mash flow through the die and the shelf life of the feed may be reduced due to the fat going rancid. However, it is a well-known fact that barns using a feeds are also less dusty. Rabbits, due to their particular way of consuming feed require a good pellet quality with minimal fines. They are extremely sensitive to the presence

Table 5: Effect on fatty acid composition of *Biceps femoris* muscle of rabbits fed Ctrl or Exp diet integrated with 6% of pistachio skin.

Fatty acids	CTRL	TRMT	SEM	*P*-values
C14	2.8	2.2	0.33	0.049
C15	0.81	0.63	0.06	0.008
C16	28.9	25.4	2.39	0.013
C16:1	3.31	3.08	0.62	0.481
C17	0.55	0.21	0.01	0.038
C18	8.81	6.33	0.83	0.003
C18:1	24.3	27.4	1.46	0.045
C18:2n-6	27.3	32.1	3.56	0.025
C18:3n-3	1.70	1.98	0.29	0.062
C20	0.50	0.48	0.13	0.402
C20:2	0.40	0.35	0.10	0.319
C20:3 n-3	0.38	0.20	0.04	0.045
SFA	42.3	35.1	2.80	0.014
MUFA	27.8	31.0	1.70	0.008
PUFA	29.7	34.5	2.80	0.032

CTRL: control diet; TRMT treatment diet; SEM: standard error of least square means. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Table 6: Effect on fatty acid composition of *Longissimus Lumborum* muscle of rabbits fed Ctrl or Exp diet integrated with 6% of pistachio skin.

Fatty acids	CTRL	TRMT	SEM	*P*-values
C14	2.41	1.30	0.33	0.041
C15	0.68	0.51	0.15	0.023
C16	29.0	26.3	3.03	0.048
C16:1	2.43	3.21	0.34	0.034
C17	0.41	0.22	0.04	0.044
C18	8.30	6.31	0.74	0.003
C18:1	25.3	27.4	1.12	0.038
C18:2n-6	26.2	29.8	1.48	0.042
C18:3n-3	2.71	2.80	0.22	0.309
C20	0.37	0.49	0.06	0.464
C20:2	0.88	0.90	0.21	0.262
C20:3 n-3	0.88	0.80	0.17	0.346
SFA	41.2	35.1	4.32	0.020
MUFA	27.8	30.8	2.12	0.041
PUFA	30.5	34.3	2.80	0.023

CTRL: control diet; TRMT treatment diet; SEM: standard error of least square means. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

of fines in the feeder, as they can enter their respiratory system and cause respiratory problems. However, Maertens (1998) recommends that fat addition in rabbit diet formulated be limited to 20-30 g kg^{-1} to avoid negative impact on pellet quality. Even though the TRMT diet formulations had one and a half times as much fat content as that in the CTRL diet, no issues were noted in terms of the physical aspects of the feed pellet or its palatability and consumption by the rabbits.

Table 2 shows that when the fatty acid profiles of the two diets are compared, the TRMT diet resulted in an increase of 9.7% in the monosaturated fatty acids and a decrease of 3.4% and 6.3% in the saturated fatty acids and polyunsaturated fatty acids, respectively. Dalle Zotte (2002) defined feeding as having a high effect on rabbit meat quality, as it influences growth performance and alters the chemical composition and quality of carcasses. However, no differences were detected between groups for growth and carcass performance and chemical composition of Biceps femoris and Longissimus lumborum muscles (Tables 3 and 4, respectively).

The fatty acid profiles of the muscles for the CTRL and TRMT groups are presented in Tables 5 and 6. In agreement with Alasnier *et al*. (1996), the loin and hind leg muscles had similar long-chain saturated fatty acid profiles in both treatment groups, showing significant decreases in some from the TRMT group. In all cases, the most abundant was recorded to be palmitic acid (C16:0), followed by stearic acid (C18:0). The TRMT group showed a significant reduction in C14:0, C15:0, C16:0, C17:0, C18:0 but not in C20:0. Various authors (Forrester-Anderson *et al*., 2006; Kouba *et al*., 2008; Kowalska and Bielanski, 2009; Dal Bosco *et al*., 2015) have all confirmed that feeding regimens are the main factors that influence the content of LCSFA, including C16:0, in fat extracted from rabbit meat (loin and hind leg). The TRMT diet had a significant effect in decreasing the overall saturated fatty acid proportions in both muscles, registering a 7% and 6% reduction in the BF and LL muscles, respectively.

The main monounsaturated fatty acid was oleic acid (C18:1n-9). In disagreement with the findings of Rasinska *et al.* (2018), the proportion of this fatty acid was similar in both muscles in the CTRL group at 24.3% in the BF and 25.3% in the LL muscle. The TRMT group had a 3% increase in both muscles compared with the CTRL group. In fact, the total monounsaturated fatty acid proportion in both muscles from the TRMT also showed the same 3% increase.

The total proportion of polyunsaturated fatty acids in fat extracted from the two muscles showed very similar values for both treatment groups. This contrasts with the findings of Rasinska *et al.* (2018). The assays of all muscles showed the predominant presence of linoleic acid (C18:2n-6). Linoleic and α-linolenic acids are considered essential fatty acids in mammals and therefore need to be derived entirely from the diet. Both fatty acids registered a significant increase in the BF muscle, while only the linoleic acid registered a significant increase in the LL muscle. Linoleic acid is essential for the synthesis of arachidonic acid (C20:4n-6), the precursor of prostaglandins and prostacyclins (reproductive function) or thromboxanes (haemostasis function). Conjugated linoleic fatty acid, which is made up of a mixture of positional and geometric isomers of linoleic acid (18:2n-6) with conjugated double bonds, has been reported to have a wide range of beneficial effects, including anticarcinogenic (Kelley *et al.*, 2007), antiatherogenic (McLeod *et al.*, 2004) and antiobesity (Whigham *et al.*, 2007) activities. Literature indicates that the main n-3 PUFA in rabbit meat is α-linolenic acid (C18:3 n-3), which is the precursor of eicosatetraenoic acid (C20:5n-3) (Enser, 1984; Sanders, 1988). Consumption of the TRMT diet significantly increased the amount of linoleic acid as well as the amount of total polyunsaturated fatty acids.

The incorporation of pistachio skins altered the fatty acid profile of the TRMT diet with the repercussion that the proportions of the ratio of SFA: MUFA: PUFA in the IMF deposition in the BF and LL muscles were also affected when compared with the CTRL group. The analysis of the BF and LL muscles of the TRMT group showed a significant increase in MUFA (3.2%, and 3.0%, P=0.008 and 0.041, respectively) and in the PUFA groups (4.8 and 3.8%, P=0.032 and 0.023, respectively), and a decrease in the SFA group (7.2 and 6.1%, P=0.014 and 0.020, respectively). It is well known that the FA levels in meat are more susceptible to being modified through the diet, as the FA are absorbed unchanged by the intestine and incorporated into tissues (Andrade *et al.*, 2018). In contrast, MUFAs and SFAs are synthesised and are less influenced by the diet than PUFAs (Wood *et al.*, 2008). This is in partial agreement with the results observed in this trial. While the amount of higher MUFA content in the TRMT diet is also represented thus in the FA profile in both muscles, the lower SFA in the test diet also resulted in a lower SFA profile in both muscles. In the case of PUFA, while having a lower content in the test diet, it still managed to evoke a higher deposition in both muscles. However, in the preparation of rabbit meat-based cuisine other rabbit carcass parts are also used. Hence, if this research included the foreleg or a whole carcass analysis, in line with the general of preparation of dishes based on rabbit meat, the odds are that significance would have been reached, as other parts are more prone to fat deposition than the BF and LL muscles (Rasinska *et al.*, 2018; Siddiqui *et al.*, 2023).

IMF is one of the main parameters influencing meat quality (Wood *et al.*, 2008), and increasing the IMF content modifies the fatty acid composition of the meat, affecting its nutritional quality (Wood *et al.*, 2017), and can have health implications for consumers. Results indicate that the IMF was modified through changes in the diet in agreement with Li *et al.* (2012) and Alfaia *et al.* (2019). That data points to the slight increase in IMF content in the BF (part of the most value cut) but not in the LL muscles of animals fed the diet with the pistachio skin inclusion. In humans, a high dietary intake of fat and SFA is related to a higher risk of cardiovascular disease (Zong *et al.*, 2016), while the intake of unsaturated fatty acids, both monounsaturated (MUFA) and polyunsaturated (PUFA), has beneficial effects (Hammad *et al.*, 2016). Nowadays, consumers are more aware of the importance of a healthy diet and demand quality products. Higher IMF content is desired to improve the juiciness, tenderness and flavour of meat (Wood *et al.*, 2008).

Although rabbit meat offers excellent nutritional and dietetic properties in itself, this study confirms that it can be further fortified with bioactive compounds to obtain meat considered functional according to the definition found in Dalle Zotte and Szendrő (2011). Various authors (Szabó *et al.*, 2001, 2002; Gigaud and Combes 2008; Maertens *et al.* 2008), confirm that the FA profile of muscles in rabbits can be effectively modified in 2–3 weeks of dietary supplementation. Hence, in the case when the supply of feed supplements is in short supply, fortified diets incorporating the supplement can be formulated as a finishing feed to be administered during the last 2 wk prior to shipping to market.

CONCLUSION

This study focused on the main muscles from the two main cuts: *Biceps femoris* from the hind leg and *Longissimus lumborum* from the loin. While the total fat quantity did not register as significant in any of the muscles from either diet, a significant effect was recorded with regard to the fatty acid profile between the two diets and between both muscles.

The LL and BF of rabbits fed on the treatment diet evidenced a decrease in the SFA content, while at the same time increasing the MUFA and PUFA content, thereby reducing the saturation, atherogenic and thrombogenic indices of the meat, with a direct consequent benefit on the nutritional quality of rabbit meat for consumers.

The integration of pistachio skins at 6% into the diet formulations intended for growing/finishing rabbits could represent a viable strategy to valorise and optimise the use of this by-product. Furthermore, fortification with PUFA meets the criteria required for rabbit meat to be considered as a functional food. However, further research is required to assess the real feasibility of the use of pistachio skin for rabbit diets in a commercial farm setting, as well as studying the implications of how to protect it from oxidation and extend its shelf life, while evaluating the organoleptic properties and consumer acceptance.

Ethics statement: The work carried out for this research was according to the Italian Policy for Animal Protection and assessed and approved by Regione Siciliana, Assessorato Regionale delle Attività' Produttive, CUP: G93F11000550004.

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