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Physicochemical Quality Attributes, Fatty Acids Profiles, Sensory Properties, and Microstructure of Rabbit Meat Fed with Agro By-Products Extracts

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Abstract

This research aims to investigate the dietary supplementation effect of agro by-products such as pomegranate peel extract (POM) orange peel extract (ORA) and corn silk extract (CS) in comparison to control (CON) supplied with a basal diet on changes in physicochemical quality attributes that include color, pH, water holding capacity WHC, cooking loss CL%, shear force, fatty acids profiles, sensory properties, and microstructure of cooked rabbit meat. Proximate compositional for different rabbit meat was carried out and the highest protein content recorded by ORA rabbit meat was 17.18%. The ultimate pH 24were determined in longissimus dorsi muscle (LD) muscle pH values are in the average range for rabbit meat. The highest pH ($p<0.05$) was recorded in the control group 6.29 while the pH decreased significantly ($p<0.05$) in POM LD muscles (5.87) followed by CS and ORA. ORA samples achieved the highest ($p<0.05$) value of lightness 63.75. The POM sample has the higher value of yellowness at 4.44 while the ORA was the lowest at 2.95 followed by CS at 3.06 and the control at 3.19. This indicates that ORA achieved the highest oxidation stability followed by CS and control. There is a non-significant difference ($p >0.05$) among all tested groups in water holding capacity in LD muscles at about 30 % and the higher score of WHC was achieved by control at 33.03 %. It was noticed that significant relation between pH and WHC (increase in pH, increase in WHC. Cooking loss (CL %) of rabbit meat samples ranged from 21.97 to 28.80% in samples cooked by boiling. Our result indicated that the CS rabbit meat sample recorded the highest cooking loss 28.80% and POM was the lowest in the cooking loss sample 21.97. There is a significant difference between all the samples. The lowest shear force recorded by ORA, CON, and CS was 23.04, 25.64, and 28.34 respectively. The highest shear force score is POM. ORA has the lowest shear force which indicates the tenderness of the meat and that was confirmed by the microstructure figure of the ORA-cooked meat. According to the findings from sensory qualities and instrumental evaluation of shear force and color, the consumers showed a preference for the ORA sample with a higher significant difference between the control and CS rabbit meat samples with a non-significant difference.

Keywords: Rabbit meat -Meat quality- Physicochemical properties -Sensory attributes-Agro by-products

1. Introduction

Nowadays, there is a rising consumer demand for a healthy way of lifestyle, specifically focusing on the nutritional value and energy of foods that are lower in cholesterol and lipid levels and high in protein value. Worldwide, rabbit meat is often a highly favored dietary item. Its consumption has recently increased in many countries Middle Eastern, European, and North African nations, special Egypt[1].

Furthermore, rabbit meat is classified as white meat that possesses a delicate flavor and can serve as a superb substitute for chicken meat [2]. As a result of the current transformation in consumer preferences toward healthier foods rabbit meat is highly recommended for patients with cardiovascular diseases, hypertension, and also young children, the elderly, and pregnant women. This is especially significant provided a recent change in consumer preferences [3].

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Orange peels and pomegranate peels are by-products that contain high levels of bioactive compounds, including flavonoids, phenolics, tannins, and pectin, which have been linked to various health benefits. Furthermore, numerous researches have documented that the extracts of pomegranate possess an impressive capacity to neutralize free radicals and exhibit antioxidant activity [4, 5].

Corn silk (CS) is a fibrous substance that exists beneath the outer husk of the corn grains which is classified as an agro-industrial product easy to obtain and low cost [6]. Many recent studies have stated that CS has lots of potential applications in health care and as an antioxidant. due to its high content of bioactive compounds including vitamins (E and K) steroids, flavonoids, phytosterols, volatile oils, saponin, alkaloids, and tannins [7,8].

From the consumer's viewpoint, people who are considered"clean and green" or "health conscious" assume that eating foods high in antioxidants, high-quality protein, and essential fatty acids will improve their health. Furthermore, market demand provides an opportunity for the industry to enhance the quality and shelf life of meat, specifically by improving its antioxidant capabilities [9].

Functional foods are found in every food category, and their functional properties can be incorporated in various ways, such as feeding animals to enhance functional nutrient levels, manipulating genetics, specific growing conditions, or selecting new species that were previously not consumed [10].

The quality of rabbit meat can be evaluated based on its chemical, physical, and sensory attributes, which are the most important to the end consumer[11]. Therefore this research aims to evaluate the effect of using agro-based by-products such as orange peel extract ORA, corn silk extract CS, and pomegranate peel extract POM as dietary supplementation that already have antioxidant capacity to improve the quality of rabbit meat compared with the control group.

2. Material and Methods

Agro by-products (pomegranate peel, orange peel, and corn silk) were extracted by researchers in the laboratory of the animal production department at the National Research Centre, Egypt according to Helal et al. [12]. One hundred growing rabbits (male New Zealand White rabbits) were purchased from a private farm. The age of the animals was 2 months at the start of the experiment and with a body weight of about 900 ± 50 g, were housed in cages made of galvanized wire mesh. The cages were supplied with feeds and automatic stainless steel nipple drinkers. Rabbits were acclimatized in cages for 5 days. Rabbits were divided randomly into 4 equal groups each group contained 5 replicates (5 rabbits for each replicate). All groups were fed a basal diet manipulated to have 2500 Kcal/kg diet digestible energy, 16% crude protein, 12 % crude fiber, and 3% fat to meet all the nutritional requirements of the breed. The first group served as the control group (without additives). The second, third, and fourth groups were given the basal diet with additions of pomegranate peel, orange peel, and corn silk extracts at a concentration of 150 ppm, respectively for 8 weeks. The concentration of supplemented extracts was quantified as the corresponding amount of vitamin E. Experimental diets were offered ad libitum and clean drinking water was freely available. Rabbits fasted overnight before butchery and were slaughtered after 8 weeks of feeding according to Islamic slaughter regulations without any harmful stress on animals during slaughtering.

2.1. Sample preparation

Four rabbit meat groups control (CON), pomegranate (POM), orange (ORA), and corn silk (CS) were chilled for 24 hours at 3°C after their Longissimus dorsi muscles from the loin (LD) were removed using the protocols established by the World Rabbit Science Association [13]. Carcasses' Longissimus dorsi muscles LD were analyzed to measure Proximate composition, pH, color, cooking losses, water holding capacity, fatty acid profile, shear force, and sensory, and A scanning electron microscope was employed for the microstructure analysis.

2.2. Physicochemical parameters

2.2. 1. Proximate compositional analysis

According to the AOAC method [14]. The moisture, protein, fat, and ash contents (g/100 g) of raw rabbit meat samples were determined for each of the four groups.

2.2.2. pH assay

The pH values of longissimus dorsi LD muscles were determined within 24 h of post-mortem using a 1:1 m/v ratio of minced muscles to redistilled water [15]

2.2.3. Color parameters

Color parameters determination 24 hours after slaughter the (lightness) L*, (redness) a*, and (yellowness) b* color parameters of the LD muscles were measured with HunterLab MiniScan XE Plus spectrocolorimeter (Hunter Associates Laboratory, Reston, VN, USA) as described by [16].

2.2.4. Determination of cooking loss

The fresh samples were weighed separately, sealed in a polyethylene bag using a vacuum, and then cooked at 80 °C for 1 hour in a water bath [17].

The temperature of cooked rabbit meats was lowered to room temperature and the cooking loss % was determined by calculating the difference in weight between raw and cooked rabbit meat samples, relative to the raw weight [18].

Cooking loss = Raw weight (g) - cooked weight (g) X 100/ Raw weight (g).

2.2.5. Water Holding Capacity

The compression technique was used to determine the water-holding capacity (WHC). [19]. A piece of meat weighing 0.3 ±0.1 g was inserted between two filter papers (Whatman no.1) and placed between two methacrylate plates, then subjected to a constant weight pressure of 10 kg for 5 minutes. We recorded three measurements of each sample. The WHC was estimated using the following equations:

WHC (%) =100 – free water

Free water = (final weight of filter paper - initial weight of filter paper/sample) × 100

2.2.6. Analysis of fatty acids

The flame ionization detector was installed on the Agilent Technologies GC model 7890B at the Central Laboratories Network, National Research Centre, located in Cairo, Egypt. The separation procedure was carried out by using a Zebron ZB-FAME column with dimensions (60 m x 0.25 mm internal diameter x 0.25 µm film thickness). Investigations were conducted in a split-1:50 mode with a flow rate of 1.8 ml/min using hydrogen as the carrier gas. The volume of injection was 1 µl and the injection volume was 1 µl. The temperature protocol is employed as follows. The temperature will be first set to 100 °C for 3 minutes. Subsequently, the temperature will progressively rise at a pace of 2.5 °C per minute until it reaches 240 °C. At this point, it will be held for 10 minutes. The injector and detector (FID) were kept at temperatures of 250 °C and 285 °C, respectively.

The saturation (S/P) and atherogenic index (AI) were calculated using the formula as follows [20]:

Saturation (S/P) $=(C14:0+C16:0+C18:0)/\sum MUFA+\sum PUFA$

$AI=[C12:0+4(C14:0)+C16:0)]/[\sum MUFA+\sum(n-6)+\sum(n-3)]$

Where PUFA are polyunsaturated and MUFA are Monounsaturated fatty

2.2.7. Shear force of cooked rabbit meat

The rabbit meat samples were defrosted in vacuum-sealed plastic bags at 4°C for 24 hours before being cooked in a water bath with automated temperature control for an hour at 80°C [21]. Shear force was measured by Brookfield texture analyzer CT3. The shear force was estimated by cutting two rectangles with a cross-section of 2-1 cm parallel to the direction of the muscle fibers [22].

2.2.8. Sensory analysis

The sensory assessment of cooked rabbit meat samples that performed heat treatment was conducted following the parameters provided by AMSA [23]. Four groups of cooked rabbit meat were analyzed for sensory characteristics. Samples were evaluated by each panelist in a random sequence, and they were asked to rate the color, appearance, flavor, tenderness, and meat juiciness using a scale between 1 (highly unacceptable) and 9 (highly acceptable). Then the assessment of the provided samples, each panelist was requested to give an evaluation for the overall acceptability. After each sample, the panelists were given drinking water to wash their palates.

2.2.9. Determination of the microstructure of cooked rabbit meat

The cooked samples were cut into pieces with dimensions of 2 × 2 × 3 mm and immersed in phosphate-buffered glutaraldehyde solution (2.5%) at a temperature of 4 ◦C for 2 hours; then the sample was rinsed with a phosphate buffer saline solution (0.1 M) and subsequently dehydrated in ethanol 50% to 100%. The samples were subjected to dry and then had gold plated by a vacuum evaporator. In the end, all samples were analyzed using a scanning electron microscope to recognize the microstructure of cooked rabbit meat samples [24].

2.3.Statistical analysis

Three replicates were used in the experiments. The statistical findings were shown using mean ± standard error format. The experimental data were assessed using one-way ANOVA and Duncan multiple comparisons, with a significance level of $P \leq 0.05$ by SPSS 15.0 for the Windows Software Package [25].

3. Results

3.1. Proximate composition

The proximate composition of rabbit meat (g/100 g) is presented in Table 1 . Rabbit meat moisture ranged from 76.98 % to 78.01%. The highest moisture content was found in CS (78.1 %) while the lowest was POM 76.89%. Protein content in rabbit meat samples ranged from 16.19 to 17.18%, the highest protein content recorded by ORA rabbit meat was 17.18% and the lowest was control sample at 16.19%. Fat content ranged from 1.12 -1.78 %. Control and CS samples possessed the highest content of fat 1.78 – 1.74 % with non-significant differences while ORA was the lowest content 1.12 %. Ash content ranged from 0.98 % in CS and 1.62% in control. There is a non-significant difference ($P > 0.05$) between ash content in CS and ORA meat samples.

Previous studies found comparable levels of water content in rabbit carcasses obtained from food chain stores in Spain [26, 27]. It also reported that the hind leg and loin (*longissimus lumborum*) in male corpses of New Zealand White rabbits fed a conventional pelleted diet had a water content of 76%, which is slightly higher [28].

Rabbit meat is an excellent protein source. The protein concentrations in rabbit carcass parts showed variation, with LD muscles containing 22.4 g/100 g protein and 18.6 g/100 g protein [29]. The protein content of *Longissimus thoracis lumborum* (LTL) and hind-leg meat varies by breed, with values ranging from 17% to 26% [30].

A study carried out using farmed hare meat revealed that the hind legs included 73.3% water, 22% protein, 2.1% lipids, and 1.35% ash. Similarly, the LD (longissimus dorsi) portion contained 75.5% water, 23% protein, 1.0% lipids, and 1.44% ash. These amounts of water and protein were greater than our protein content, while the water concentration was somewhat lower [31].

It was reported that the composition of nutrients in rabbit meat may be influenced by both intrinsic as well as extrinsic variables, such as husbandry, diet, genotype, sex, and age [32,33].

Table 1: Proximate composition of different rabbit meat (fresh tissue)

sample	moisture	Protein	Fat	Ash
CON	$77.7^{b} \pm 0.1$	$16.19^{a} \pm 0.35$	$1.78^{b} \pm 0.02$	$1.62^{c} \pm 0.04$
POM	$76.89^{a} \pm 0.03$	$16.95^{b} \pm 0.05$	$1.67^{b} \pm 0.1$	$1.31^{b} \pm 0.02$
ORA	$76.98^{a} \pm 0.03$	$17.18^{c} \pm 0.12$	$1.12^{a} \pm 0.1$	$1.05^{a} \pm 0.12$
CS	$78.01^{c} \pm 0.01$	$16.19^{a} \pm 0.21$	$1.74^{b} \pm 0.04$	$0.98^{a} \pm 0.02$

Mean values (± S.D.) followed by different letters in the column are significantly different ($P \leq 0.05$)

3.2. Fatty acids profile

The lipid profile of rabbit meat is highly advantageous probably due to its significant amounts of polyunsaturated (MUFA), monounsaturated (PUFA), and fatty acids (FA), in addition to important odd-numbered straight-chain and methyl-branched-chain FAs (OBCFA), which are absent in beef and poultry lipids [34]. Incorporating special plant bioactive compounds into rabbit feed can modify varied meat quality parameters, including fatty acid composition [35, 36].

POM showed a high level of saturated fatty acids (ΣSFA) followed by ORA, CS, and the control. On the other hand, POM contained the maximum quantity of total monounsaturated fatty acids (ΣMUFA). In terms of total polyunsaturated fatty acids, ΣPUFFA was highest in the control group, followed by CS, ORA, and POM respectively.

The n – 6/n – 3 fatty acid ratios raised from 7.81 to 9.10 in fats of animals fed with POM while the lowest ratio was in ORA 7.78. The dietary value of fats is typically described using these ratios, and the better the value is the lower the ratio [37].

The PUFA level, n–6/n–3 fatty acid ratios, and the saturation (S/P) vary depending on the animals' age, sex, nutrition, genotype, breeding, and/or physical activity of the animals [38].

All rabbit meat recorded a higher content of Palmitic acid C16:0 than the control, it was reported that the primary factor that influences the C16:0 contents of fat in rabbit meat is the dietary regimen [39]. It was also observed that the fats of animals that fed conventional diets contained significantly higher levels of C16:0 [40].

3.3. Rabbit meat pH, color, and water holding capacity

A further significant indication of meat quality is the acidity (pH) of meat, which is measured 24 hours after slaughter [41]. The pH level of rabbit meat is an important factor that inhibits the microorganism's growth due to the bacteriostatic effect of low pH and determines its shelf life, It also affects the technological usability, and quality of the rabbit meat, several factors, such as muscle type, stress during slaughter and transport [42]

The ultimate pH 24, color, and water-holding capacity were determined in LD muscles and the results are presented in Table 3. Concerning pH24 in LD muscles, all pH values are in the normal range for rabbit meat. However, there is a significant difference between control LD muscles and all other groups. The lowest pH was reported in POM LD muscles (5.87) followed by CS and ORA. However, control LD muscles had the highest pH (6.28).As observed (pH45) of lower than 6.0. After post–mortem muscle glycogen is transformed into lactic acid, leading to a reduction in the pH values below 6.0 in carcasses. The decreased pH of these muscles enhances their

ability to be stored for longer periods and inhibits bacterial growth and activity [43], which reveals that the supplementation with POM, CS, and ORA inhibited the growth of microorganisms (bacteriostatic effect of low pH), improved the shelf life and rabbit meat quality.

Meat's characteristics, especially its color parameters, are directly correlated with pH, which also affects the oxidation of hemoglobin and the muscle texture.

Color parameters (L*, a*, b*) of LD muscles were determined and it is observed that ORA achieved the highest value of lightness 63.75 followed by CS 62.69 while control was the lowest in lightness 53.28. It is well known, that muscle myofibrillar protein shrinking which is negatively connected with pH level causes an increase in meat lightness, e.g. the lower the pH, the lighter the meat. Additionally, there is a strong relationship between the color of red meat and pH [44].

The results presented that the ORA LD muscles group achieved the highest redness value (2.4 respectively)

Table 2: Fatty acids in fat extracted from meat rabbits

Name	CON	POM	ORA	CS
C10:0	0.04	0.02	0.06	0.02
C10:0	0.11	0.09	0.10	0.04
C14:0	2.63	3.93	3.22	2.97
C15:0	0.62	0.58	0.64	0.56
C16:0	25.18	31.5	30.35	30.52
C17:0	0.83	0.73	0.85	0.75
C18:0	7.28	6.97	7.45	7.21
C20:0	0.22	0.18	0.19	0.19
C21:0	0.03	0.03	0.03	0.01
C22:0	0.02	0.02	0.02	0.02
C24:0	0.05	0.08	0.04	0.04
C14:1	0.09	0.2	0.13	0.1
C15:1	0.17	0.12	0.16	0.12
C16:1	3.01	4.16	2.87	3.14
C17:1	0.32	0.26	0.28	0.27
C18:1	24.91	24.46	24.93	24.25
C20:1	0.28	0.26	0.33	0.29
C20:1	0.21	0.15	0.18	0.21
C18:2(n-6)	30.31	23.36	25.20	25.61
C18:3(n-3)	0.06	0.06	0.05	0.28
C18:3(n-3)	3.1	2.42	2.59	2.82
C 20:3(n-3)	0.07	0.07	0.06	0.01
C20:4(n-6)	0.32	0.31	0.23	0.16
EPA C20:5(n-3)	0.07	0.04	0.02	0.4
DHA C22:6 (n-3)	0.06	0.01	0.01	0.02
ΣSFA	37.01	44.13	42.95	42.33
ΣMUFA	28.99	29.61	28.88	28.38
ΣPUFA	33.99	26.27	28.16	29.3
ΣPUFA (n-3)	3.92	2.60	3.27	3.25
ΣPUFA (n-6)	30.63	23.67	25.43	25.77
n-6/ n-3	7.81	9.10	7.78	7.93
Saturation (S/P)	0.56	0.76	0.72	0.71

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; PUFA (n – 6): polyunsaturated fatty acid series n – 6; PUFA (n - 3): polyunsaturated fatty acid series n – 3; S/P: saturated fatty acid/unsaturated fatty acid

while the lowest value of redness was reported in in POM, and CS in LD muscles groups (0.16, 0.35 respectively). This may be attributed to the increasing level of metmyoglobin, which is considered a product of oxidation [45]. This apparent delay in the discoloration of the meat, compared to previous research, suggests a possible indication of the meat's oxidative stability.

The POM sample has the higher value of yellowness at 4.44 while the ORA was the lowest at 2.95 followed by CS at 3.06 and the control at 3.19. It has been reported that higher values of yellowness were associated with the presence of free radicals, which are formed by lipid oxidation during storage and thermal stress/or manipulation, which has the potential to cause oxidation of haem, resulting in the discoloration of meat and meat products [46]. This indicates that ORA achieved the highest oxidation stability followed by CS and control.

Water holding capacity in LD muscles for all tested groups ranged from 30.35 to 33.03 % and the higher score of WHC was achieved by control at 33.03 %. The results show a non-significant difference between POM, ORA, and CS in WHC in LD muscles while there is a significant difference between them and the

control. The relation between pH and WHC was observed to be relevant (increase in pH, increase in WHC) [47, 48] Conversely, enterocins and sage extract resulted in a decrease in pH and an increase in WHC. Our findings are comparable to the WHC values reported which ranged from 32.20 to 33.33 after the supplementation of rabbit diets with Eleutherococcus senticosus, sage, and oregano extracts [49, 50]. It also stated that the loss of water in meat increases when the pH decreases due to the muscle proteins being closer to the isoelectric point, which leads to a lower degree of hydration [51].

Table 3: Rabbit meat pH, color, and water-holding capacity of *longissimus dorsi* muscles

Parameters	CON	POM	ORA	CS
pH_{24}	6.28^{c}±0.02	5.87^{a}±0.02	5.95^{b}±0.04	5.93^{b}±0.03
L	53.28^{a}±0.30	55.37^{b}±1.06	63.75^{d}±0.05	62.69^{c}±0.04
a	1.63^{b}±0.13	0.16^{a}±0.01	2.4^{c}±0.40	0.35^{a}±0.05
b	3.19^{c}±0.01	4.44^{d}±0.06	2.95^{a}±0.05	3.06^{b}±0.06
WHC	33.03^{b}±0.07	30.92^{a}±0.11	30.47^{a}±0.50	30.35^{a}±0.37

Mean values (± S.D.) followed by different letters in the row are significantly different (P ≤0.05) from each other

3.4 Cooking loss and shear force

The cooking loss (CL %) of rabbit meat samples cooked by boiling is shown in Table 4 which ranges from 21.97 to 28.80%. Our result revealed that the CS rabbit meat sample recorded the highest cooking loss 28.80% and POM was the lowest in the cooking loss sample 21.97. There is a non-significant difference between the CON sample and the POM rabbit meat sample. A high CL% of boiled beef steak was observed as a result of the prolonged duration required for boiling [52,53].

Table 4: Cooking loss and shear force in rabbit meat by boiling

Sample	Cooking Loss%	Shear force (N)
Control	22.13^{a} ± 0.13	25.64^{b} ± 0.04
pomegranate	21.97^{a} ± 0.27	29.82^{d}± 0.08
Orange	27.26^{b} ± 0.18	23.04^{a} ± 0.12
Corn Silk	28.80^{c} ± 0.16	28.34^{c} ± 0.26

Mean values (± S.D.) followed by different letters in the column are significantly different (P ≤0.05

The shear force was used to determine the tenderness of the cooked rabbit meat samples and the results are shown in Table 4. There is a significant difference between all the samples the lowest shear force recorded by ORA, CON, and CS was 23.04,25.64 and 28.34 respectively.
The highest shear force score is POM. This indicates that ORA possesses a better technological and texture quality than the control.

3.5 Sensory evaluation

Cooking affected quality attributes, such as appearance, color, flavor, tenderness, and juiciness shown in Table 5. In this regard, we found that the orange rabbit meat sample recorded the highest score in all tested parameters, and the high score in appearance could agree with pH, color, and shear force results of ORA., The high score in juiciness and tenderness may be due to lower cooking loss and the lowest score in sensory quality attributes was recorded by POM.
According to results from evaluating the sensory qualities and using instrumental evaluation to measure shear force and color, the consumers showed a preference for the ORA sample with a higher significant difference than CON and CS rabbit meat samples with non-significant differences.

Table 5: Sensory analysis of cooked rabbit meat by boiling

Sensory characterization	CON	POM	ORA	CS
Appearance	7.20^{a} ±1.03	8.20^{b} ±0.80	8.60^{b} ±0.52	8.00^{b} ±0.67
Color	7.80^{a} ±0.79	8.20^{a}±0.79	9.20^{b} ±0.79	8.00^{a} ±0.66
Flavor	7.00^{a} ±1.49	8.20^{b} ±0.78	9.20^{c} ±0.78	8.70^{b}±0.42
Tenderness	6.80^{a} ±1.22	7.80^{b} ± 0.78	9.00^{c}±0.67	7.80^{b} ± 0.78
Juiciness	5.40^{a} ±1.42	8.20^{b} ±0.79	8.60^{b} ±0.52	7.90^{b} ±0.84
overall	7.60^{b} ±0.52	6.60^{a} ±0.84	8.60^{c} ±0.79	7.40^{b}±0.84

Mean values (± S.D.) followed by different letters in the row are significantly different (P ≤0.05) from each other

3.6 Microstructure of cooked rabbit meats

The microstructure of rabbit meat samples cooked by boiling for 30 min at 100° C was shown in Fig 1. Connective tissues could be observed among the muscle bundle in all samples but a certain amount

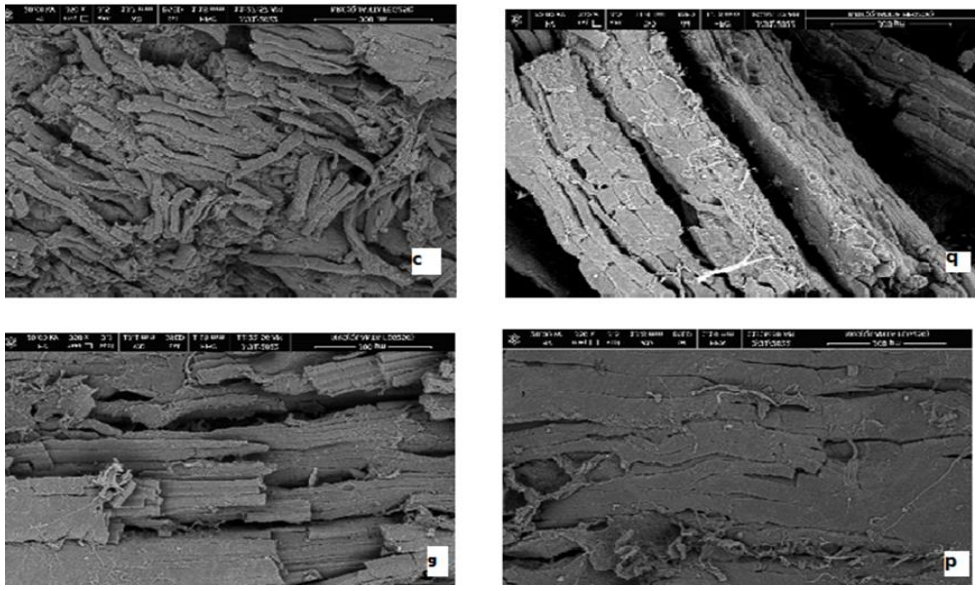

Fig 1: The microstructure structure of cooked rabbit meat a) CON b)POM c)ORA d) CS

could appear as a network in POM, CON, and CS samples (a,b,d), little amount appeared as coagulated in control and ORA (c) and appeared as a homogenous mass in POM (b). The cleavage along

muscle fibers was in all samples but was the highest in ORA and CS. There is also an increase in the inter myofiber spaces in CS samples. The control and CS samples revealed the highest number of gaps between the muscle fibers compared to the other samples.
There is a strongly destructive effect on connective tissues and muscle fibers in control, ORA, and CS. The sensory attributes and instrumental evaluation (shear force) results reveal that the structural integrity of both muscle fiber and connective tissue elements was altered, leading to an increased tenderness of the ORA-cooked rabbit meat samples. This finding is supported by the sensory analysis data and the correlation with shear force. Therefore, consumers preferred the ORA and control-cooked rabbit samples. The histological structure of meat is significantly affected by heating. That change includes the denaturation and aggregation of myofibrillar and sarcoplasmic proteins. Furthermore, the texture of heated meat can be impacted by the formation of a gel network due to the melting of collagen [54].

4. Conclusion

In conclusion, our results concluded that feeding rabbits with agro by-products such as ORA extracts containing bioactive compounds could be used as a promising strategy to produce high meat quality attributes for consumers. The highest protein content recorded by ORA rabbit meat was 17.18%. ORA and CS achieved good values in color parameters indicating high oxidative stability. ORA has the lowest shear force which indicates the tenderness of the meat and that was confirmed by the microstructure figure of the ORA-cooked meat. According to the results obtained from the sensory characteristics and instrumental evaluation for determining shear force and color, consumers showed a preference for the ORA sample with a highly significant difference from the control and CS rabbit meat samples with a non-significant difference. ORA was the most effective extract that improved oxidative stability and rabbit meat's technological and sensory quality.

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6-Conflicts of interest

The authors have no conflicts of interest to declare.

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