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Article

Effect of hydrostatic pressure on some quality properties in Iraqi rams and calves' meats.

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ABSTRACT

Two experiments have been conducted in this research to determine the effects of hydrostatic pressure on Iraqi rams and calves' meats. (One experiment for each kind of meat), Four treatments were designed for each experiment: control with no hydrostatic pressure, T1 with 100 bar exposed pressure, T2 with 200 bar and T3 with 300 bar. The pressures were generated and handled via a device designed and manufactured for this goal. The studied properties were water holding capacity WHC, thaw loss, fragmentation index FI, myofibril fragmentation index MFI, protein solubility and shear force. All these properties are strongly related to meat tenderness. All studied properties were affected significantly by applying hydrostatic pressure on meat samples to rams and calves' meat samples. Therefore, exposing the meat to hydrostatic pressure enhances its tenderness-related properties.

Keywords: hydrostatic pressure; tenderness; Protein solubility.

INTRODUCTION

A very high percentage of animals are culled annually for many reasons, including aging [1]. Aging is the primary reason behind the worldwide decrease in tenderness in all kinds of meats. Tenderness is the first quality consumers would feel when chewing a piece of meat under the teeth [2]. Picard and Gagaoua [3] have defined it as the easiness that meat insidious compositions collapse under teeth. Tenderness is one of three attributes that determine meats' palatability, flavor, and juiciness [4]. Despite tenderness being the attribute, many researchers have tested, it is still elusive, and its subtle mechanisms are well because of the many factors that stand in the background, like age, gender, breed, species, enzyme activity and so on [1, 5]. So, many researchers focused on enhancing tenderness via developing many technical or chemical techniques that would have reflected on the meat industry field directly or indirectly [2].
All enhancing tenderness techniques, including both pre-slaughter and post-slaughter factors, depend on the treatments after slaughter until reaching the enzymatic analysis and far [6]. The most common tenderizing process is traditional aging, the oldest one ever, which depends upon leaving carcasses for some time to enhance their flavor and texture (ripening) [7]. Tenderizing by electrical stimulation is another technique; this process depends on fastening glycogen analysis inside muscles and producing lactic acid, whereas the muscle's pH reaches 6 before the temperature reaches 10 Celsius. That means that this process is conducted after slaughter directly [8, 9.] Mechanical tenderization is another process for tenderizing meat; it is applying meat after slaughter

to processes like hanging, mincing, cutting or even cooking; all these processes are aimed to enhance the palatability of meats by enhancing tenderness and its relatives' attributes [10, 11]. Chemical tenderization demands adding specific chemicals to have a positive effect on tenderness. This may be salts, phosphate, or organic acid. The positive effect would occur via manipulating the meat properties related to tenderness like protein solubility, water holding capacity, collagen contents and so on [12, 13]. Many other tenderizing processes exist, like enzymatic and ultrasonic tenderizing, and so on [14]. The goal of this research is to investigate another kind of tenderizing technique. Testing a process of exposing Iraqi rams and calves' meats to hydrostatic pressure and measuring the effects that can appear in tenderness-related properties that reflect the meat's tenderness status.

MATERIALS AND METHODS

Hydrostatic pressure generator device

Figure 1 refers to a locally-made device. This device can generate hydrostatic pressure by pressing water trapped inside a closed cylindrical shape container. The compressed water is in contact with meat samples inside the same container, where the meat samples go under hydrostatic pressure for a specific period, and the changes are measured afterward. The parts of the device are:
1- The steel frame: Holds all the device's parts and the function of assembling all other parts.
2- Hydraulic pump: Generates hydraulic pressure {reaches to 400 bar (Kg/cm^2).}
3- The cylindrical pressure container: This is the central part of the device and has two sections. The first one receives the pressure (as a compressed liquid) from the pump via specific high-pressure tubes. The second section is a cavern container containing the samples, filled with water and tidied up before being exposed to pressure. Between these two sects, there is a kit of specific rubber diaphragms to prevent oil and water from being mixed.
4- The pressure gauge: To measure the amount of exposed pressure by bar unit or (Kg/cm^2).
5- The spring: Reset the device after each operation.

Experiments

Two experiments were conducted in this research. The first uses Iraqi ram meat, while the second uses Iraqi calves' meat.
Experiment one: an amount of Iraqi ram meat from the right leg (femoral) was used in this exp. Which was purchased from the local market in Kerbala / Iraq. The meats were cut into four, each weighing 300 g. Then, each part of these four was distributed to treatments.
Experiment two: an amount of Iraqi calves' meat from the right leg (round) was used in this exp. Which was purchased from the local market in Kerbala/ Iraq. The meats were cut into four, each weighing 300 g. Then, each part of these four was distributed to treatments.

Treatments

for each experiment, four treatments have been conducted:
- Control treatment CONT.: no hydrostatic pressure has been conducted at all.
- Treatment one T1: Five minutes of 100 bar hydrostatic pressure was applied to the meat samples.
- Treatment two T2: Five-minute 200 bar hydrostatic pressure was applied to the meat samples.
- Treatment three T3: 300 bar hydrostatic pressure was applied to the meat samples for five minutes.

Studied properties

- Water holding capacity WHC: what Dolatowski and Stasiak [15] mentioned but with some modifications. 50 ml from each sample was taken and homogenized with distilled water for one minute and then centrifuged at 5000 rpm for ten minutes. WHC was (added water weight- removed water)/sample weight 100.
- Thaw loss percentage: which was calculated via the process of Denhertog-Meische et al. [16]. Samples from each treatment were weighted and frozen under -20CO under vacuum condition for two weeks in plastic bags,

then thawed in the refrigerator at 4 CO overnight, weighted again after removing thaw liquids. Thaw loss was calculated using the formula (sample weight after freezing – sample weight after thawing)/ sample weight after freezingX100.

• fragmentation index FI: FI value was measured according to Davis et al. [17]. The values would be distributed from (100 to tender meats to 600 to tough meat)

• Myofibril fragmentation index MFI: as Culler et al. [18] mentioned, the NFI has been calculated.

• protein solubility: these values were evaluated according to Denthertog-Meische et al. [16], and calculated the final values via the process of Gomell et al. [19]

• Shear force: as recorded by Abdulla et al. [20] by using the Warner-Bratezler device. A piece of meat from each sample was taken (diameters of 2cm thick and 10 cm long), cooked in a water bath (without touching the water) for 90 minutes at 70 Co., and then cooled in the refrigerator overnight before being exposed to the W-B device. The W-B device is designed to conduct pressure to a knife edge and record the sample resistance to cut, representing the tenderness or toughness of meat samples.

Statistical analysis

All values recorded were analyzed by CRD design, and the comparison between treatments was obtained using the Duncan test.

RESULTS

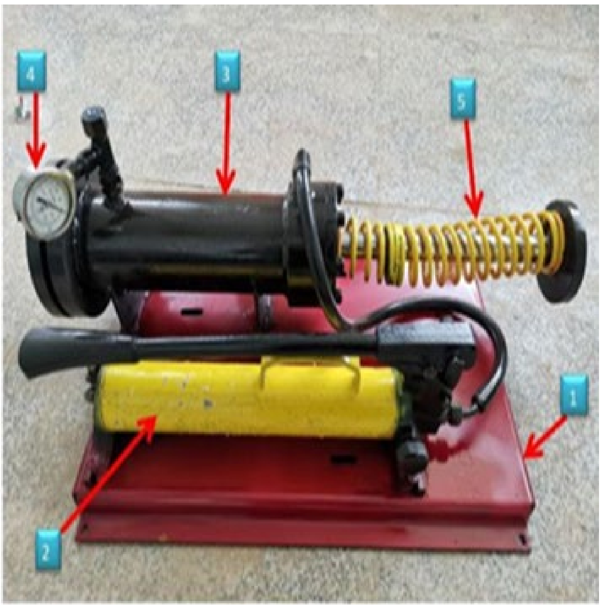

Figure 1. Hydrostatic pressure generator device.

Water holding capacity WHC

Table 1 illustrates the differences between treatments in water holding capacity WHC trait. For both ram and calves meat, the treatment with 300 bars scored the highest values, 35 and 40 for both calves and rams, respectively, compared with the lowest value that belonged to the control for each experiment.

TRT.	Pressure value (bar)	WHC percentage in Iraqi calves' meat	WHC percentage in Iraqi ram meat
Cont.	zero	10 ±0.5 d	12 ±0.61 d
T1	100	20±0.1 c	23±0.21 c
T2	200	31±0.22 b	33±0.2 b
T3	300	35±0.11 a	40±0.02 a

[1]T. Different letters in each column show significant differences between treatments ($p \leq 0.05$).
Table 1. The effect of hydrostatic pressure on WHC in Iraqi rams and calves' meats.

Thaw loss

Table 2 shows an enhancement in thaw loss (decreasing value) by applying more hydrostatic pressure for both experiments. Even though the enhancement in calves' meat was insignificant under all kinds of pressure, the pressure treatment overlapped the control (without pressure). In the rams' meat experiment, the enhancement was more noticeable even though there were no significant differences between T1 and T2. However, the values all differentiated obviously.

TRT.	Pressure value (bar)	Thaw loss value (rams meat)	Thaw loss value (calves meat)
Cont.	Zero	4.3±0.4 a	3.5±0.6 a
T1	100	3.1±0.32 b	2±0.7 b
T2	200	2.9±0.52 b	2.1±0.4 b
T3	300	2.1±0.4 c	1.8±0.5 b

[2]T. Different letters in each column show significant differences between treatments ($p \leq 0.05$).
Table 2. The effect of hydrostatic pressure on Thaw loss values in Iraqi rams and calves' meats.

Fragmentation index FI

From Table 3, it is evident that the value of IF differed significantly with increasing hydrostatic pressure. IF value Proportional reversely to meat tenderness. A high IF value means less tenderness and vice versa. The highest values were related to control treatment for calves' and rams' meat samples. That means the meats with no pressure exposure had less tenderness status. At the same time, the highest values were related to the treatment of 300 bar (T3s) for each experiment. That means the more pressure exposed, the more tender meats. Moreover, this new tenderization process could be helpful as a new technique in this process.

TRT.	Pressure value (bar)	Tenderness statue (rams meat)	FI values (rams meat)	Tenderness statue (calves meat)	FI values (calves meat)
Cont.	Zero	Rather tender	254±6 a	Rather tender	292±6.3 a
T1	100	Tender	200±4.5 b	tender	274±5 b
T2	200	More tender	199±4.7 b	More tender	199±7.7 c
T3	300	Much more ten-der	137±1.77 d	Much more tender	187±1.3 d

[3]T. Different letters in each column show significant differences between treatments ($p \leq 0.05$).
Table 3. The effect of hydrostatic pressure on fragmentation index (FI) values in Iraqi rams and calves' meats.

Myofibril fragmentation index MFI

TRT.	Pressure value (bar)	Tenderness statue (rams meat)	MFI (rams meat)	Tenderness statue (calves meat)	MFI (calves meat)
Cont.	Zero	Tenderness meat	55±0.88 c	Rather tenderness	50±0.09 b
T1	100	Rather tenderness	53±0.09 d	Rather tenderness	52±0.07 b
T2	200	More tenderness	66±0.34 b	Tenderness meat	68±0.07 a
T3	300	Much more tenderness	68±0.81 a	Tenderness meat	67±0.09 a

[4]T. Different letters in each column show significant differences between treatments (p≤0.05).
Table 4. The effect of hydrostatic pressure on myofibril fragmentation index (MFI) values in Iraqi rams and calves' meats.

It can be seen from Table 4 that the property of MFI was significantly different with pressure differences applied. The highest value was recorded in T3 (300 bar) for experiments 67 and 68 for calves' meat and rams' meat, respectively. At the same time, the lowest values belonged to control for each treatment. This means a noticeable enhancement could occur when exposing meat to hydrostatic pressure.

Protein Solubility

TRT.	Pressure value (bar)	Protein solubility Mg/g (rams meat)	Protein solubility Mg/g (calves meat)
Cont.	zero	70±0.1 a	62.3±0.1 a
T1	100	71.89±0.72 a	58.8±0.07 b
T2	200	62±0.44 b	56±0.1 c
T3	300	44.2±0.34 c	51.5±0.09 d

[5]T. Different letters in each column show significant differences between treatments (p≤0.05).
Table 5: The effect of hydrostatic pressure on protein solubility values in Iraqi rams and calves' meats.

Table 5 illustrates significant differences between myofibril protein solubility treatments with increasing hydrostatic pressure. The highest values came from the highest pressure and vice versa in each experiment. Otherwise, in the ram experiment, no significant differences were observed between the control treatment and T1 (100 bar), while noticeable significant differences occurred among all others.

Shear Force

The adequate force required to cut a specific piece of meat is shear. Table 6 exhibits these values for both experiments. It could be shown that the highest values were obtained from control treatments for calves 4.48 Kg and rams 4.55 Kg, respectively. At the same time, the lowest ones were from T3s at 3.39 Kg and 2.68 Kg for calves' and rams' meat samples, respectively. The results strongly confirm this research's hypothesis by relating the amount of hydrostatic pressure applied and the enhancement in tenderness as a reflection of easiness undercutting.

TRT.	Pressure value (bar)	Shear force Kg (rams meat)	Shear force Kg (calves meat)
Cont.	zero	4.550±0.07 a	5.480±0.05 a
T1	100	3.860 ±0.01 b	4.460 ±0.04 b
T2	200	3.210±0.02 c	4.100±0.08 c
T3	300	2.680±0.09 d	3.390±0.03 d

[6]T. Different letters in each column show significant differences between treatments ($p \leq 0.05$).

Table 6. The effect of hydrostatic pressure on shear force values in Iraqi rams and calves' meats.

DISCUSSION

The property of WHC is one of the critical properties in meat science because of its importance for both producers and consumers of meat. This trait is related to other important traits like juiciness and tenderness, so its value would affect the tenderness directly. WHC correlated with meat protein surface area, which could form a bond with water and couch it down. Meats that can catch water are often better from chemical and nutritional aspects [21]. This experiment accorded with what was obtained by Bertram [22], who mentioned that a decrease in WHC value means a reduction in meat value on the myofibril plane—losing water after thawing had been mentioned in more than one research [23]. While Moreno et al., [24] referred to the relation between this character and the statue of myofibril proteins, the bonds could be formed with water. In general, this trait is related to WHC and complemented with it. In our research, exposing hydrostatic pressure enhances these two properties.

The property of FI is considered a good indicator for measuring collagen defragmentation and other connective tissues; this is why this trait is always connected with tenderness [17]. The decrease in number means more fragmentation cases decreasing in the precipitate, which means more tenderness [25]. This fact is ours. So, the fact abstracted from our results is that the more pressure exposed, the more tender the meats are. MFI trait differs from FI because the rise in MFI value means an increase in tenderness in contrast with FI, in which the rise in its value means a decrease in tenderness. More than one research pointed out that myofibril proteins are the majority of protein contents in striated muscles, responsible for transferring the movement to the skeleton via contraction-relaxation operation. So, myofibril proteins are continuously changing during an animal's lifetime [26]. From a meat science aspect, myofibril status reflects the history of pressure muscles are exposed to during animal life. For that, the ability of myofibril to fragment is related to animal age and its physiological conditions—the more the ability to fragment, the more tenderness meats obtain [27]. The results of this experiment showed that there is a response in the MFI trait after exposing meat samples to hydrostatic pressure.

Moreover, exposing meat to controlled hydrostatic pressure could be a new process in meat tenderization. The results were accorded with Koohmaraie and Whipple [28], who said that the MFI could indicate tenderness and the carcasses' development after slaughter and rigor mortis. Exposing meat to hydrostatic pressure could be an assistant factor in shortening the period of rigor mortis and fastening and getting rid of it. This may be a good factor in the meat industry.

Protein solubility may be defined as a more profound status of myofibril fragmentation index (MFI). Myofibril protein molecules become smaller and lighter in molecular weight, so they have more ability to solubility [29]. The same research referred to myofibril protein solubility related to animal age and its physiological condition, rather more, type and location of the muscles in the body. Our results showed a relation between pressure and protein solubility; the more pressure applied; the more solubility recorded. ThusExposing hydrostatic pressure is a new technique in this process. The results of these two experiments in this research came across with those of Swatland [30] and Lyon and Lyon [31], who both referred to the relationship between shear force and meat tenderness.

CONCLUSIONS

Applying hydrostatic pressure on meat enhances the tenderness property and other related characteristics. Therefore, these results may be a starting point for developing a new tenderization process and all its other applications. It is recommended to conduct another research aiming for another kind of meat or with another amount of pressure to confirm the results.

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