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Effect of cooking conditions on physico-chemical and textural properties of Emu *(Dromaius novaehollandiae)* meat

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Abstract

The Emu meat *(Dromaius novaehollandiae)* was cooked at various cooking temperatures; 40, 50 and 60°C, for various cooking time; 5, 10 and 15 min. The effect of cooking temperature and time on quality of Emu *(Dromaius novaehollandiae)* meat such as cooking loss, cooking yield, protein content, moisture content, colour and textural properties (hardness, springiness, cohesiveness, chewiness, resilience) of raw and cooked meats were investigated. Cooking loss, change in thickness, L^*, b^* value, chroma (C^*), and hue angle (h) were increased with increasing cooking temperature and time. Cooking yield, changes in length, breadth, volume, mass, density, moisture content, a^* value, pH and protein content were decreased with increasing cooking temperature and time. Changes in textural properties also observed. Statistical analysis shows the cooking time and temperature had higher significant effect ($P<0.01$) on all the parameters studied. The interaction effect of cooking temperature and time was non significant for textural and colour properties. The combined effect of cooking temperature and time was significant for moisture content, protein content, and changes in length, thickness, cook loss and cooking yield.

Introduction

Meat continues to be an important food group in the diet of most consumers, particularly in the developed world (Delgado, 2003). Many factors such as wealth, volume of livestock production and socio-economic status of consumers would explain the higher consumption pattern of meat by western population (Speedy, 2003). Exotic meats are gaining popularity in the global meat market, where health-conscious consumers are becoming increasingly careful in choosing lean meat alternatives over traditional meats (Daniel *et al*., 2000; Hoffman, 2008). Among exotic meat species, Ratites received significant attention as producers of low-fat meats (Andrews *et al*., 2000). Ratites are a family of flightless birds, such as ostrich, emu, and rhea, which now are intensively farmed for their valuable products, including meat.

Foods such as meat and fish become edible and more digestible when they are subjected to cooking. The purpose of cooking is to make meat palatable, digestible, microbiologically safe and to improve its hygienic quality. Meat undergoes many changes during cooking including weight loss, textural changes, muscle fibre shrinkage and colour that are strongly dependent on protein denaturation and water loss (Walsh *et al*., 2010). Quality characteristics such as texture, protein content, cooking yield, juiciness, colour and flavour of cooked meat products are affected by the composition, characteristics of the muscles, heating method, cooking time and temperature (Bouton and Harris,1981; Christensen *et al*., 2000). The relationship between texture and heat-induced denaturation of meat protein, changes in connective tissue, soluble proteins, and myofibrillar proteins have been reported (Hearne *et al*., 1978; Martens *et al*., 1982). The effects of cooking temperatures and cooking methods on beef muscle have been studied (Obuz *et al*., 2004, Yancey *et al*., 2011). They revealed that a lower cooking temperature yielded a tender product with lower cooking losses. Texture changes during processing are a result of complex chemical changes. Different cooking techniques, duration of cooking and core temperature have a great effect on the physical properties of meat and its eating quality (Combes *et al*., 2003). The meat shrinkage and expansion varies with different muscles and temperature (Mora *et al*., 2011). The change in water content is contributed to changes in sarcomere length and juiciness with temperatures (Laakkonen *et al*., 1970).

The relationships between processing temperature and quality factors such as texture, protein content,

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cooking yield, juiciness, colour and flavour are important in improving the design and operation of thermal processes for foods. When cooking is performed in hot waterbath there is an optimal time and temperature for processing desired quality such as protein denaturation and other physical characteristics (Lund, 2003).

Emu *(Dromaius novaehollandiae)* is the second largest bird in the world and is the largest avian species native to Australia, where commercial Emu farming is successful since the 1980's. Till date there is no study carried out on the effect of cooking time and cooking temperature on Emu meat quality. So an attempt was made to study the effect of cooking temperature and time on Emu meat physico-chemical and textural properties. This work is part of a comprehensive study on Emu meat cooking, where the general aim is optimization of the process for development of emu meat based products. In this way, the specific objective of this work was cooking of Emu meat at low temperature with high protein content and low cooking loss.

Materials and Methods

Meat samples

Fresh boneless and skinless Emu *(Dromaius novaehollandiae)* leg muscle samples were collected from female Emu slaughtered at the Emu Vijay Protein farm, Tambaram, Chennai, Tamilnadu, India. The animals were 2–3 years old weighing 35-40 kg. The samples were collected within 6 h post-mortem. The samples were wrapped in sterile polyethylene bags and placed in a thermocool container filled with ice and transported to the Department of Food Process Engineering laboratory, SRM University, Kattankulathur, Kancheepuram District, Tamil Nadu, India for use in the experiments. The samples were cut to about 2x2x1 cm steaks and kept in the refrigerator at 4 ± 1°C for about 24 h.

Cooking treatments

The steaks were directly cooked in vessel with equal amount of water which was kept in waterbath for controlling cooking temperature. The steaks were introduced for cooking after reaching the preset temperature. The steaks were cooked at three different temperatures; 40, 50 and 60°C for three different times; 5, 10 and 15 minutes. Immediately after cooking, cooked samples were analysed

Moisture content

Moisture content of raw and cooked Emu meat was measured by Hot air oven method (AOAC, 1980). Moisture content of sample was determined for raw and cooked Emu meat samples by weight loss at 105°C to constant weight in hot air oven by using the following formulae:

$$\text{Moisture content (\%) w.b} = ((M_1 - M_2)/M_1) \times 100$$

Where,

M_1 = Initial weight of meat sample, g
M_2 = Final weight of meat sample, g
(%) w.b = percentage wet basis

pH

The pH of raw and cooked meat samples were measured using a digital pH meter (Cyber-14L pH meter) (AOAC method.,1980; Dzudie *et al.*,2000). About 10 g of ground meat sample was homogenized with 100 ml of distilled water in a laboratory blender for about 1 min and the pH was recorded. The pH value of raw meat was measured at room temperature just prior to cooking. The pH of the cooked meat was measured after cooking, once the temperature of the meat reached room temperature

Total protein content

Protein content of raw and cooked meat samples were determined by AOAC (2000) Kjeldhal method.

Cooking loss and Cooking yield

Cooking loss was calculated as weight difference between fresh and cooked samples relative to the weight of fresh meat samples in percentage.

$$\text{Cooking Loss (\%)} = ((W_1 - W_2)/W_1) \times 100$$
$$\text{Cooking Yield (\%)} = (W_2/W_1) \times 100$$

Where,

W_1—Weight before cooking, g
W_2—Weight after cooking, g

Colour

The CIE lab coordinates (L^*, a^* and b^*) of raw and cooked meat samples were directly read in a glass cuvett with a spectrophoto calorimeter Miniscan MS/Y/2500 (Hunterlab, Reston,VA,USA). The instrument was calibrated using white calibrated tile prior to use. L^* (lightness), a^* (redness), and b^* (yellowness) were measured. The individual differences in L^*, a^* and b^* values of each cooking treatments with respect to the colour of the raw samples (r) were evaluated using ΔE. Chrome (C^*), hue angle (h) in degree were calculated by using the formula described by Garcia-Segovia *et al*. (2007).

Table 1. Moisture content, pH, protein content, cooking loss and cooking yield of raw and cooked Emu meat samples at different cooking temperature and time

Cooking Temperature (°C)	Cooking Time (min)	Moisture content (%w.b)	pH	Protein content (%)	Cooking loss (%)	Cooking Yield (%)
Raw meat		$74.79^{h}\pm0.17$	$6.22^{e}\pm0.03$	$24.39^{f}\pm0.64$	-	-
40	5	$74.11^{g}\pm0.13$	$6.2^{de}\pm0.03$	$23.88^{f}\pm0.7$	$14.33^{a}\pm2.1$	$85.67^{e}\pm2.1$
40	10	$73.21^{f}\pm0.10$	$6.18^{bcd}\pm0.02$	$22.95^{e}\pm0.62$	$20.79^{b}\pm2.5$	$79.21^{d}\pm2.5$
40	15	$71.94^{e}\pm0.11$	$6.15^{bc}\pm0.06$	$22.07^{d}\pm0.52$	$28.63^{c}\pm3.3$	$71.37^{c}\pm3.3$
50	5	$73.26^{f}\pm0.10$	$6.18^{bcd}\pm0.05$	$20.80^{e}\pm0.64$	$17.23^{a}\pm2.8$	$82.77^{e}\pm2.8$
50	10	$72.09^{e}\pm0.10$	$6.16^{bcd}\pm0.04$	$22.01^{d}\pm0.65$	$23.369^{b}\pm3.3$	$76.61^{d}\pm3.3$
50	15	$70.96^{c}\pm0.27$	$6.13^{ab}\pm0.04$	$20.86^{c}\pm0.62$	$33.42^{d}\pm4.2$	$66.58^{b}\pm4.2$
60	5	$71.57^{d}\pm0.23$	$6.16^{bcd}\pm0.03$	$20.81^{c}\pm0.54$	$23.61^{b}\pm2.7$	$76.39^{d}\pm2.7$
60	10	$69.09^{b}\pm0.11$	$6.13^{ab}\pm0.04$	$19.22^{b}\pm0.55$	$33.03^{d}\pm3.1$	$66.97^{b}\pm3.1$
60	15	$68.11^{a}\pm0.17$	$6.1^{a}\pm0.03$	$17.07^{a}\pm0.41$	$45.64^{e}\pm4.3$	$54.36^{a}\pm4.3$
P value						
Temperature		<0.001	<0.01	<0.001	<0.001	<0.001
Time		<0.001	<0.01	<0.001	<0.001	<0.001
Temperature*Time		<0.001	NS	<0.01	<0.05	<0.05

Note: Values with different superscripts in a column are differ significantly at $P \leq 0.05$
NS-Not significant

h = arch tan (b^*/a^*)
$C^* = (a^{*2}+b^{*2})^{1/2}$
For red hue, hue angle (h) is 0° and for yellowish hue, hue angle (h) is 90°

Effect of cooking on linear dimensions, mass, volume and density

Changes in the length (L), breadth (B) and thickness (T); mass (M), volume (V) and density (D) during cooking were evaluated. Length, breadth, thickness of the steaks was measured before and after cooking as per the procedure outlined by Mora et al. (2011). Each parameter was expressed as the ratio (dimensionless) between before cooking (i) and after cooking value (f) such as Lf/Li, Bf/Bi, Tf/Ti, Mf/Mi, Vf/Vi and Df/Di, where, Lf-Length after cooking; Li-Length before cooking; Bf- Breadth after cooking; Bi-Breadth before cooking; Tf- Thickness after cooking; Ti-Thickness before cooking; Df-Density before cooking; Di-Density after cooking; Mf-Mass before cooking; Mi-Mass after cooking; Vf-Volume after cooking; Vi-Volume after cooking

Texture profile analysis

Texture Analyser TA-XT Plus (Stable Micro Systems) provided with the software "Texture Expert" and equipped with a 75 mm diameter aluminium cylindrical compression probe attached to a 0.5 KN load cell was used to study the textural properties of raw and cooked Emu meat. Three slices of 20 mm thick Emu meat steaks were compressed to 50% of their original height in a Texture profile analysis double compression test at 5 mm/s speed test, with a 7 s delay between first and second compression. Textural properties such as hardness (N), cohesiveness, springiness (mm), chewiness (N-mm) and resilience were found following the procedures described by Cheng and Sun (2004).

Statistical analysis

Emu meat was cooked at various cooking temperature such as 40, 50 and 60°C for different cooking time; 5, 10 and 15 min. Data were analysed by two way ANOVA using IBM SPSS statistic version 19.0 software. The significant differences between treatments were verified by Duncan multiple range test (DMRT) at $P<0.05$. Values are referred in results as means ± Standard deviation.

Results and Discussion

Moisture content

Moisture contents of cooked samples in all cooking treatments are shown in Table 1. Moisture content was significantly decreased ($P<0.01$) with increasing cooking temperature and time. Moisture content reduction during cooking is consistent with cooking loss and cooking yield. Moisture content was decreased 3.81%, 5.12% and 8.93% with respect to raw meat during 40ºC, 50ºC and 60ºC cooking for 15 min.

Table 2. Colour properties of raw and cooked Emu meat samples at different cooking temperature and time

Cooking Temperature (°C)	Cooking Time (min)	L*	a*	b*	C*	h	ΔE
Raw meat		44.18^{a}±0.72	7.53^{h}±0.05	7.74^{a}±0.56	10.78^{a}±0.75	45.78^{a}±0.17	-
40	5	47.87^{b}±0.76	6.85^{g}±0.06	8.15^{ab}±0.29	10.65^{a}±0.26	49.94^{b}±0.81	3.78^{a}±0.77
40	10	48.43^{bc}±0.62	6.54^{ef}±0.06	8.56^{bc}±0.23	10.77^{ab}±0.22	52.61^{c}±0.55	4.44^{ab}±0.62
40	15	49.33^{bc}±0.63	6.19^{bcd}±0.6	9.08^{cde}±0.19	10.99^{abc}±0.19	55.71^{d}±0.35	5.49^{bc}±0.63
50	5	48.76^{bc}±0.62	6.8^{fg}±0.05	8.65^{bcd}±0.24	11.00^{abc}±0.22	51.82^{c}±0.6	4.73^{abc}±0.63
50	10	49.52^{c}±0.62	6.48^{de}±0.04	9.14^{cde}±0.21	11.20^{abc}±0.19	54.66^{d}±0488	5.62^{bcd}±0.63
50	15	50.63^{cd}±069	6.11^{bc}±0.06	9.64^{ef}±0.57	11.42^{bcd}±0.51	57.59^{e}±1.3	6.88^{de}±0.78
60	5	49.67^{cd}±0.61	6.32^{cde}±0.05	9.34^{def}±0.49	11.3^{abcd}±0.43	55.89^{d}±1.2	5.85^{cde}±0.68
60	10	50.69^{d}±0.81	6.01^{b}±0.06	9.94^{fg}±0.48	11.62^{cd}±0.44	58.83^{e}±1.0	7.04^{e}±0.88
60	15	51.87^{e}±0.65	5.61^{a}±0.05	10.54^{g}±0.31	11.94^{d}±0.29	61.97^{f}±0.53	8.41^{f}±0.67
P value							
Temperature		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Time		<0.001	<0.001	<0.001	<0.05	<0.001	<0.001
Temperature *Time		NS	NS	NS	NS	NS	<0.001

Note: Values with different superscripts in a column are differ significantly at $P \leq 0.05$
NS-Not significant

pH

The mean pH of raw and cooked meat samples are shown in Table 1. pH was significantly increased with cooking time ($P<0.05$) and temperature ($P<0.01$). pH value of Emu meat is on par with the result obtained by Menon *et al.* (2014).

Total protein content

The protein content of raw and cooked Emu meat are presented in Table1. During cooking, protein content was significantly decreased with increasing temperature ($P<0.001$) and time of cooking ($P<0.001$). Protein content decreased 9.51%, 14.47% and 30.01% respectively during 40ºC, 50ºC and 60ºC cooking for 15 min cooking time with respect to raw meat. These results were on par with previous reports (Murphy and Marks, 2000). This may be due to denaturation of sarcoplasmic protein. Emu meat is rich in myoglobin which is the sarcoplasmic heme protein (Suman *et al*., 2010; Menon *et al*., 2014). Bouton and Harris (1972) established that the sarcoplasmic protein was completely denatured at 62ºC in beef.

From the Table 1, it can be observed that the protein content of meat cooked at 40°C for 10 min, 50°C for 10 and 60°C for 5 were coming under same group. The meat cooked at 50°C cooking temperature and 10 min cooking time is having 22.01% protein content which was 5.45% higher than the meat cooked at 60°C cooking temperature and 5 min cooking time.

Cooking loss and Cooking yield

The cooking loss and cooking yield of Emu meat cooked at various temperatures; 40, 50 and 60ºC for different time intervals; 5, 10 and 15 min are shown in Table 1. Cooking loss significantly increased with temperature ($P<0.001$) and time ($P<0.01$). Cooking yield significantly decreased with temperature ($P<0.001$) and time ($P<0.01$). The highest cooking loss and lowest cooking yield was observed at 60ºC, 15 min cooking and lowest cooking loss and highest cooking yield was observed at 40ºC and 5 min cooking time. Similar cooking loss results were observed by the authors who worked on cooked meat (Combes *et al.*, 2003; Obuz *et al*., 2003; Cheng *et al*., 2004; Garcia-segovia *et al*., 2007; Vasanthi *et al*.,2007; Yancey *et al.*, 2011). More cooking loss and less cooking yield were observed in samples cooked at 50 to 60ºC than those in samples cooked at 40 to 50ºC at different cooking time examined. Palka and Daun (1999) also observed the highest cooking loss at 50-60°C. Cooking loss is a result of changes in two main structural protein systems of meat namely actomysin complex and collagen (Garcia-Segovia *et al*., 2007).

Laakkonen *et al.* (1970) and Hearne *et al.* (1978) have found the reduction in cooking yield with cooking time and temperature in different types of meats. Kiran *et al.* (2014) also found cooking yield in spent hen meat. Hearne *et al*. (1978) states that the reduction in cooking yield is due to cook drip and evaporative loss. From the Table 2, it can be observed that the cooking loss and cooking yield of

Table 3. Ratios of linear dimensions, mass, volume and density of Emu meat cooked at different cooking temperature and time

Cooking Temperature (°C)	Cooking Time (min)	Lf/Li	Bf/Bi	Tf/Ti	Mf/Mi	Vf/Vi	Df/Di
40	5	$0.99^{f}\pm0.001$	$0.955^{ef}\pm0.002$	$0.913^{a}\pm0.005$	$0.957^{a}\pm0.008$	$0.95^{e}\pm0.006$	$1.007^{a}\pm0.003$
40	10	$0.98^{f}\pm0.002$	$0.945^{e}\pm0.005$	$0.94^{b}\pm0.006$	$0.936^{b}\pm0.009$	$0.945^{e}\pm0.005$	$0.989^{d}\pm0.005$
40	15	$0.98^{f}\pm0.002$	$0.937^{d}\pm0.007$	$0.97^{c}\pm0.006$	$0.91^{d}\pm0.01$	$0.93^{d}\pm0.003$	$0.982^{bc}\pm0.008$
50	5	$0.95^{e}\pm0.002$	$0.93^{cd}\pm0.005$	$0.98^{c}\pm0.007$	$0.92^{de}\pm0.008$	$0.92^{d}\pm0.006$	$1^{cd}\pm0.003$
50	10	$0.94^{d}\pm0.001$	$0.93^{cd}\pm0.005$	$1.03^{d}\pm0.009$	$0.89^{c}\pm0.015$	$0.9^{c}\pm0.007$	$0.986^{bc}\pm0.009$
50	15	$0.92^{c}\pm0.001$	$0.926^{c}\pm0.004$	$1.05^{e}\pm0.006$	$0.87^{b}\pm0.013$	$0.89^{c}\pm0.005$	$0.974^{ab}\pm0.009$
60	5	$0.91^{b}\pm0.001$	$0.93^{cd}\pm0.005$	$1.06^{f}\pm0.001$	$0.88^{bc}\pm0.008$	$0.89^{c}\pm0.01$	$0.986^{bc}\pm0.003$
60	10	$0.91^{b}\pm0.002$	$0.917^{b}\pm0.003$	$1.1^{g}\pm0.007$	$0.86^{b}\pm0.009$	$0.87^{b}\pm0.007$	$0.98^{bc}\pm0.003$
60	15	$0.87^{a}\pm0.004$	$0.903^{a}\pm0.006$	$1.12^{h}\pm0.009$	$0.827^{a}\pm0.01$	$0.86^{a}\pm0.01$	$0.966^{a}\pm0.008$
P value							
Temperature		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Time		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Temperature*Time		<0.001	NS	<0.05	NS	NS	NS

Note: Values with different superscripts in a column are differ significantly at P≤0.05
NS-Not significant

meat cooked at 40°C for 10min, 50°C for10 min and 60°C for 5 min were coming under same group.

Colour

L^*, a^*, b^*, Chroma(C^*) and hue angle (h) in degree for fresh and cooked emu meat samples are tabulated in Table 1. The meat samples cooked at various temperature shows significant difference in L^*, a^*, b^* values. The cooked samples have higher L^* value (lighter in colour) and higher b^* value (more yellow) than raw meat. L^* and b^* values were significantly increased with increasing temperature ($P<0.001$) and time ($P<0.01$). The a^* value is significantly decreased ($P<0.001$) with increasing cooking temperature and time. Similar colour changes were observed by Garcia-Segovia *et al.* (2007); Yancey *et al.* (2011). Denaturation of myoglobin (a pigment most responsible for the red colour) begins between 55°C and 65°C. This is the reason for the colour changes in meat during cooking (King and Whyte, 2006). ΔE values increased with respect to cooking temperature and time. ΔE values confirm the colour changes with temperature and time.

Effect of cooking on linear dimensions, mass, volume and density

Lf/Li value is decreased significantly with respect to temperature ($P<0.001$) and non significant with time ($P>0.05$). Bf/Bi, Vf/Vi, Mf/Mi and Df/Di values were significantly decreased with increasing time and temperature (Table 3). Bf/Bi value is more in 40°C at 5 min and less in 60°C at 15 min. i.e the shrinkage is more in higher temperature. Tornberg (2005) stated that the transverse shrinkage occurs in the temperature range of 40-60°C by widening the gap already existing between the fibres and their surrounding endomysium at rigor. In case of Tf/Ti, the opposite trend was observed. Tf/Ti increased with temperature ($P<0.001$) and time ($P<0.01$). The highest Tf/Ti value was observed in 60°C at 15 min and lowest value in 40°C at 5 min cooking (Table 3). The mean Lf/Li and Bf/Bi values are lower than 1 and Tf/Ti value is more than 1. Our results support with the previous work done by Pan and Singh (2001); Mora *et al.*, (2011), where meat has shrunk in two dimensions and expanded in the third dimension.

Texture profile analysis

The textural properties of raw and cooked Emu meat are tabulated in Table 4. The results shows hardness was increased from 40 to 50ºC and decreased at 60ºC. Statistical analysis shows hardness significantly changing with respect to temperature ($P<0.01$) and decreased with respect to time ($P<0.01$). Hardness increased by 8.66% and 11.15% with respect to raw meat during 40°C and 50°C cooking for 15 min cooking time. The increase in hardness is due to thermal shrinkage of the connective tissue and denaturation of myofibrillar proteins (Christensen *et al.* 2000). During cooking of meat at 60°C for 15 min, a reduction of 3.47% was observed with respect to raw meat. This reduction in hardness (tenderness) is due to softening of connective tissue in 50 to 60°C. These results are in agreement with previous studies conducted by Christensen *et al.* (2000), Combes *et al.* (2003) and Li *et al.* (2013).

Table 4. Textural properties of raw and cooked Emu meat samples at different cooking temperature and time

Cooking Temperature (°C)	Cooking Time (min)	Hardness (N)	Springiness (mm)	Cohesiveness	Chewiness (N-mm)	Resilience
Raw meat		$72.54^{cd}±2.42$	$0.48^{a}±0.003$	$0.61^{f}±0.006$	$21.2^{bcd}±1.05$	$0.19^{g}±0.007$
40	5	$75.28^{de}±2.26$	$0.49^{a}±0.003$	$0.598^{f}±0.006$	$22.07^{cde}±0.91$	$0.18f^{g}±0.006$
40	10	$77.05^{ef}±2.23$	$0.5^{cd}±0.003$	$0.59^{de}±0.006$	$22.79^{def}±0.84$	$0.16^{bcd}±0.007$
40	15	$78.82^{ef}±1.35$	$0.51^{e}±0.003$	$0.58^{cd}±0.006$	$23.53^{ef}±0.76$	$0.14^{a}±0.006$
50	5	$77.06^{ef}±2.74$	$0.5^{c}±0.003$	$0.59^{de}±0.006$	$22.52^{def}±1.2$	$0.18^{ef}±0.006$
50	10	$78.83^{ef}±1.75$	$0.51^{de}±0.003$	$0.58^{cd}±0.006$	$23.42^{ef}±0.94$	$0.17^{de}±0.007$
50	15	$80.63^{f}±1.73$	$0.52^{e}±0.003$	$0.574^{bc}±0.01$	$24.1^{f}±1.4$	$0.15^{abc}±0.007$
60	5	$64.12^{a}±1.91$	$0.50^{cd}±0.003$	$0.575^{bc}±0.005$	$18.51^{a}±0.79$	$0.16^{cde}±0.007$
60	10	$67.06^{ab}±1.91$	$0.52^{e}±0.003$	$0.561^{b}±0.006$	$19.56^{ab}±0.8$	$0.15^{ab}±0.008$
60	15	$70.02^{bc}±2.28$	$0.54^{f}±0.003$	$0.546^{a}±0.006$	$20.5^{bc}±1.02$	$0.14^{a}±0.007$
P value						
Temperature		<0.001	<0.001	<0.001	<0.001	<0.01
Time		<0.01	<0.001	<0.001	<0.01	<0.001
Temperature*Time		NS	NS	NS	NS	NS

Note: Values with different superscripts in a column are differ significantly at $P≤0.05$
NS-Not significant

Springiness decreased with temperature ($P<0.01$) and time ($P<0.01$). Springiness is affected by myosin and alpha actinin denaturation which occur in the temperature range of 50ºC (Cheng and Parrish, 1979, Martens *et al*., 1982). Cohesiveness increased with time ($P<0.01$) and temperature ($P<0.01$). As chewiness is a product of hardness, springiness and cohesiveness, it changed significantly with cooking temperature ($P<0.01$) and temperature ($P<0.05$).

Conclusion

Cooking temperature and time play an important role in protein content, physical and textural properties of Emu meat. Meat cooked at higher cooking temperature (60ºC) had lower cooking yield with more cooking loss, less moisture and less protein content. This is related to moisture loss and protein denaturation. Texture Profile Analysis (TPA) measurements also shows significant effect of cooking temperature and time on Emu meat texture. In the present study, it is concluded that cooking of Emu meat at 50ºC for 10 min is suitable for precooking with minimum cooking loss, protein loss and acceptable texture. The precooked Emu meat can be used for preparation of meat powder for the development of meat based products such as soups, meals with gravy and flavour enhancer. The combined effect of cooking temperature and cooking time was non significant for textural and colour properties. The combination of cooking temperature and time was influenced on moisture content, protein content, changes in length and thickness, cook loss and cooking yield.

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