CARCASS CHARACTERISTICS AND MEAT QUALITY OF EMUS – A PILOT STUDY

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CERTIFICATE

This is to certify that the thesis entitled "**CARCASS CHARACTERISTICS AND MEAT QUALITY OF EMUS – A PILOT STUDY"** submitted in partial fulfillment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY in MEAT SCIENCE AND TECHNOLOGY to the TAMIL NADU VETERINARY AND ANIMAL SCIENCES UNIVERSITY, CHENNAI – 51, is a record of bonafide research work carried out by R. RAMANI, under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

CARCASS CHARACTERISTICS AND MEAT QUALITY TRAITS OF EMUS – A PILOT STUDY

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A study on the carcass characteristics, meat quality traits including amino acid profile, fatty acid profile and mineral content estimation along with organoleptic and microbial quality of emu of the age groups 15 and 18 months were carried out. Eight birds were slaughtered from each group. Value added products were prepared from emu meat and compared with those made from beef and chicken. The physicochemical properties were assessed at 0, 1st, 2nd and 7th day. The samples were kept in chiller (0°C ± 1°C) upto 1st day and then in freezer (-18°C ± 1°C) upto 7 days for further assessment. Quality traits were also analysed on three different muscle regions, viz., drumstick, thigh and breast of emu.

Significant and progressive increase in live weight and carcass weight was observed with increase in age whereas the meat: bone ratio decreased significantly. Drip loss and cooking loss were higher in the 18 month age group. A mean dressing percent of 65.06 and 67.95 in both the age groups was recorded. The mean per cent yield of edible offals such as heart, liver, kidney and gizzard were 1.35 and 1.39, 1.43 and 1.45, 0.65 and 0.74, 1.18 and 1.22, respectively. The mean percent yield of

inedible offals, viz., recorded for blood, feather, skin, shank, head, lungs, intestines, proventriculus, spleen, trachea, oesophagus and wings of 15 and 18 months age groups were 1.20 and 1.63, 0.41 and 0.55, 2.81 and 3.19, 1.06 and 1.38, 0.31 and 0.36, 0.30 and 0.35, and 0.59 and 0.70, 0.15 and 0.07, 0.03 and 0.07, 0.14 and 0.16, 0.14 and 0.12 and 0.05 and 0.07, respectively.

There was a linear increase in the weights and yields of edible and inedible offals with age. However, the yields of offals such as skin, head and intestines did not differ significantly ($P>0.05$) with increase in age. A highly significant increase in the yield of cut up parts such as neck, breast and rib and loin were observed with increase in age, whereas a highly significant decrease in the weights of cut up parts such as drumstick, thigh and rump was observed with increase in age. The increase in the yields of fat and bone were highly significant in the 18 month age group.

The progressive fall in pH values (5.66 – 5.52) during the periods of storage in chiller and freezer indicated the normal trend. Decrease in the water holding capacity was observed with increase in chronological age and with storage periods. Different muscle regions also showed a highly significant difference in the water holding capacity. The R- value obtained in this study at 1^{st} day ranged from 1.06 -1.24 in both the age groups indicating the onset of rigor mortis at chiller storage during this period.

The extract release volumes of both the age groups increased gradually and consistently throughout the storage period. The thiobarbituric acid number and tyrosine values increased significantly at different storage periods for both the age groups and there was no significant difference in the tyrosine values between the age groups.

The fibre diameters increased gradually as age advanced (14.35µm – 17.27 µm) and decreased with storage periods. The sarcomere length revealed significant

decrease as age advanced (2.92 μm – 2.23 μm) and increased with storage periods. Significant difference was noticed in the myofibrillar fragmentation index between the age groups and the myofibrillar fragmentation increased with storage. The myoglobin percent, shear force values and collage contents increased significantly with age. The drumstick region had the highest and the breast region the lowest values.

Spectrophotometric assay of meat colour revealed that the younger age groups had higher lightness (L*), lower redness (a*) and yellowness (b*) values. Drumstick region revealed to have minimal lightness (L*) and intense redness (a*) and the thigh region was found to be intermediary. The breast region had the highest lightness (L*) and lowest redness (a*) values. Hue values were more in drumstick and the breast showed more chroma values.

The texture profile values reflected the younger groups to have favourable textural properties pertaining to tenderness of meat. The texture profile results revealed that the younger age groups had decreased hardness, springiness, cohesiveness, gumminess and chewiness values than the older birds. The texture parameters also indicated drumstick to be a less tender region than the thigh and breast.

There was increased percentage of moisture and protein observed in the younger age groups. The fat and cholesterol percentages were very less in the younger group which is of concern to nutritionists. The comparative analysis of the proximate composition in emu, beef and chicken meat revealed that emu meat had the highest protein and lowest fat and cholesterol percentage.

The saturated fatty acids were significantly higher in the older age groups. The monounsaturated and polyunsaturated fatty acids were more in the younger age

groups. Oleic acid (C18:1) was the predominant monounsaturated fatty acid and the polyunsaturated fatty acids such as the linoleic (C18:2) and linolenic (C18:3) were all significantly higher in the younger groups.

It was observed that the mineral contents between the muscle regions as well as between the age groups of emu birds differed with high significance. The minerals magnesium, calcium, sodium and zinc were found to be more in younger animals than the older groups.

The emu meat from the younger age groups exhibited higher scores for all the sensory parameters. Decreased scores for tenderness and juiciness were given to the older age groups by the sensory panelists. Microbiological quality revealed no significant difference ($P>0.05$) between the two age groups.

Between the products of emu, beef and chicken, emu sausages and nuggets exhibited less intense colour. The texture profile analysis of the products revealed a highly significant difference ($P<0.01$) between the products as well as between the different species. Emu products exhibited lesser values of all the textural attributes than beef but were more than chicken. Emu sausages and nuggets exhibited more stability and product yield values than beef and lower values than chicken.

Emu products received more panelists score compared to beef in appearance, tenderness and juiciness. Microbial quality of the products prepared from emu, beef and chicken showed a significantly higher difference in the microbial counts at different storage periods. However, the counts were within the acceptable limits. Hematoxylin and Eosin stained muscle tissue sections of emu, beef and chicken revealed that the fibre diameters of emu tissues (12 µm – 14µm) were similar to that of chicken (11 µm - 13µm) than beef (23 µm - 30µm).

The results of the study indicated that emu of 15 months age group can be advocated for meat production considering the various favourable characteristics like meat : bone ratio, high meat yield (drumstick and thigh cuts), reduced drip loss and cooking loss, and the meat quality traits like pH, water holding capacity, R – value, extract release volume, thiobarbituric acid number, tyrosine value, fibre diameter, sarcomere length, myofibrillar fragmentation index, myoglobin percent, shear force value and collagen content, instrumental analysis of colour, texture profile analysis, proximate composition and cholesterol content, amino acid profile, fatty acid profile, mineral content. The organoleptic scores also were supportive to the 15 month age group. The comparison of value added products were favourable to emu meat.

CHAPTER I

INTRODUCTION

Meat is an excellent source of good quality animal protein which provides all the essential amino acids and various micro nutrients in proper proportion to the human beings. It remains to be an economically important, nutritionally valuable and organoleptically enjoyable commodity to the consumer.

The present global meat production is around 285.5 million metric tonnes (FAO, 2011), of which India's contribution is 4.16 million metric tonnes (1.46%), placing it in 8th rank. Despite Indian meat production racing on an upward curve, India displays to be the world's less meat consuming country (5kg/year) with the annual per capita availability of meat as low as 14 g/day against the ICMR recommendation of 34 g/day in India.

Over population and shrinkage of cultivable land due to urbanization and industrialization pose great challenges to the scientists and food producers to cater to the ever increasing protein demand which will in turn alleviate malnutrition and that is prevalent in the country leading to kwashiorkor, marasmas and anaemia in a vast majority of the Indian population particularly women and young children.

Malnutrition can only be overcome with the effective utilization of meat resources compared to plant protein because of their increased bioavailability and production ability. Diversification of species is one such effective utilization strategy of meat resource, which will fulfill the protein demand and thereby eradicate malnutrition and anaemic deficiencies.

Also the awareness on the nutritive value of food have pressurized producers to supply the needs of consumers not only in the perspective of hygienic and qualitative production but also to concentrate on nutritive production.

It is proved that red meat has more bio availability with increasing proportion of heme iron than plant based protein foods. Further, it is recognized as a significant source of heme iron compared to poultry and fish (Johnston *et al*, 2007), and an useful source of bioavailable zinc, vitamins like riboflavin (B_6), cyanocobalamin (B_{12}), caliciferol (D), minerals like calcium, folate and selenium (National Health and Medical Research Council, 2006; World Cancer Research Fund/ American Institute for Cancer Research, 2007) contributing to cancer protection under various situations (Ferguson, *et al*., 2004a and 2004b).

But the misconceptions towards red meat (beef, mutton, chevon and pork) consumption and the association of several cholesterol associated problems and heart diseases with meat consumption and the ever persisting religious taboo on beef slaughter and consumption have created a thrust to look for an alternative red meat that will meet the highest protein and iron requirements, but with lowest cholesterol and at the same time of high nutritive value invariably consumed by all the communities as well as by all age groups in India. In the current scenario, the best alternative of red meat with the above expected perspectives emerges to be the Emu meat!

Emu (*Dromaius novaehollandiae*) an emigrant of Australia, a large flightless bird, belonging to Ratite subfamily with innate disease resistance and adaptability to varied climatic conditions has acclimatized itself to thrive well in a tropical country like India and has set its foot prints in Indian poultry industry remarkably. The technical and economic feasibility of emus in India has contributed to the increasing popularity and recognition of emu farming in recent years.

Emu is an omnivorous bird weighing around 45- 60 kg with a height of about 6 feet. Simple nutritional requirement as that of chicken and limited managerial need

of emu has attracted the attention of industrial entrepreneurs towards large investments in emu farming. Yet, ever since the start of commercial emu industry, much attention has been focussed only on emu oil production owing to its cosmetic and pharmaceutical utility and also on other marketable emu products from egg shell, leather and feathers.

Lack of knowledge and awareness of beneficial properties of emu meat has hampered the effective utilization of emu meat for human consumption and has compelled it to remain an accessory and not a main product of this industry. This scenario needs to be changed to attempt for an efficient utilization of this lean red meat thereby fulfilling the protein demand and alleviating malnutrition and anaemia.

Emu meat tends to be of interest to health conscious meat eaters owing to its specific characteristics of subcutaneous fat deposition unlike other red meat and lesser intramuscular fat. The meat is found to have lower fat and calorific value than beef, pork and chicken but similar to deer meat with highest iron sodium content (Daniel *et al*., 1997).

The ω-3 and ω-6 polyunsaturated fatty acids (PUFA) derived from α-linolenic and linoleic acids, respectively of emu meat fitted well within the recommended range (4:1 to 10:1) for human health (Health and Welfare, Canada, 1990). The intake of these unsaturated PUFA reduces lipid oxidation to a great extent preventing the formation of atherogenic, mutagenic and cytotoxic compounds and thus the probable risk of human health (Fernandez *et al*., 2005).

Higher creatine levels were detected in emu jerky (1,553mg/100g) than in beef jerky (1,518mg/100g) demonstrating the potential of a processed emu meat snack to be considered as a functional food for athletes looking for performance enhancement,

and who are interested in consuming greater quantities of creatine from a natural food source (Pegg *et al.,* 2006).

Although some research work has been documented on nutritional and managemental aspects of emus, no work has been carried on the carcass characteristics and meat quality traits of emus bred and grown in India. Hence, the present study has been carried out with the following objectives.

- To study the carcass characteristics of emu.
- To study the physico-chemical and textural properties of emu meat.
- To estimate the proximate composition of emu meat.
- To analyse the amino acid and fatty acid profile and mineral content in emu meat.
- To compare the organoleptic and eating quality characteristics of emu meat sausages and nuggets with that of chicken and beef.
- To assess the microbiological quality of emu meat and meat products.

The current research work would thus widen the existing knowledge on the emu meat, with respect to its carcass yield, texture, the amino acid and fatty acid profiles and cholesterol content.

This study would lead to the awareness on the carcass characteristics and quality traits of emu meat at its marketing age and thereby enable the entrepreneurs to adopt strategies for proper feeding and management of these birds to attain the required carcass yield of emu meat in turn making the farming of emu economically sustainable.

Moreover, the comparison of value added products from emu meat with that of the commonly used meat products would open up the venue for entrepreneurs to widen marketing of emu meat and meat products.

CHAPTER II

REVIEW OF LITERATURE

2.1 History

The Emu (Dromaius novaehollandiae) is a large, flightless bird belonging to the order, STRUTHIONIFORMES, and the family CASAURIDAE, which also includes the ostrich, rhea, kiwi and cassowary (Sibley and Ahlquist, 1990). The word ratite is used to describe the entire group of large birds. The word comes from the Latin word, “ratis”, which describes the flat breast bone, where sternum has a keel like a boat (Minaar and Minaar, 1992).

The Emu, a native of Australia is of the same family as that of the African Ostrich and the South American Rhea. The U.S. has an emerging emu industry with a flock exceeding half of a million birds that are raised in atleast 43 states (Ford, 1994).

Despite an attempt in 1970 to farm emu in Western Australia for leather production, emu were only recognized as an agricultural commodity in Australia in 1987 (Drenowatz *et al*., 1995). Emus have been hunted by humans, who have certainly been the emu’s greatest predator since the middle upper Meistoscene (Boland, 2003), for over 60,000 years throughout inland Australia (Kirk, 1981).

The height of an adult emu ranges from 5 to 6 feet tall, and the bird can weigh up to 150 pounds. Visual differences between males and females are not readily apparent, and a popular method to distinguish male from female is vent sexing (Minaar and Minaar, 1992).

Contrary to two digits in the ostrich foot, the emu foot, similar to rhea and cassowary, has three digits (Fowler, 1991). Swart *et al*., (1993) observed anatomical difference especially in the size of colon of Emu, Ostrich and Rhea. Four bellies and not the usual three, in the

Muscularis gastrocnemius (the most powerful muscle in the shank) distinguish emus from other avian species (Patak and Baldwin, 1998).

Most cladistic analysis using skeletal, molecular and zoological data agree on a close relationship between cassowaries and emus (Zelenitsky and Modesto, 2003).

Emus have wings, with a single clawed digit that are tiny stub – like appendages that hang from the anterior region of the body (Maxwell and Larsson, 2007).

2.1.1 Emu production

In 1987, the Western Australian Department of Agriculture approved the establishment of licensed, commercial emu production due to increased popularity and recognition of emu farming as economically and technically feasible (Smetana, 1993). Texas emu farmers have established a national association to advocate the improvement and research of emu farming as an alternative livestock (Minaar and Minaar, 1992)

Emu production is relatively easy, but developments in emu processing and marketing have not kept pace with emu production (Frapple and Hagan, 1992).

Jeffery, (1998) considered the limited amount of land required to raise emu as an advantage. He thought that nutritional requirements of emus were similar to that of chicken although there has been little scientific research to support this.

The industry is attempting to market its three major products, meat, oil and leather in a market which has almost no knowledge of them" (Frapple and Hagan, 1992). Emu breeders, in an effort to promote the growth of their industry, have developed many national, state and local associations and two cooperatives (Thompson, 1995).

Increasingly, attention is being paid to ratites (ostrich, emu and rhea) as producers of low fat red meat. Although, some work has been conducted on emu meat quality (Jones and

Robertson, 1995; Berge *et al*., 1997), no information is available on carcass yield from the emu.

Fronteddu, (2001) was of the opinion that, ever since the start of the development of the commercial emu industry around 1990 most of the attention is focused on oil production and its potential use in the cosmetic, pharmaceutical and medicinal industries. However, emu are also valued for their low-fat red meat and hides in making of leather products. Other potentially marketable emu products include feathers, eggs, egg shells, toe nails, bones and manure.

Emu are considered as an alternative form of livestock, which has spurred an increase in their production. It produces red meat that is similar to beef but has less fat content (Kenji Maehashi *et al*., 2009). They are reared commercially in many parts of the world for their meat, oil, skin and feathers which are of high economic value (Patodkar *et al*., 2009).

2.1.2 Emu meat

Emu meat is a red meat and has a flavor similar to beef but is much leaner and lower in fat (Minaar and Minaar, 1992). The emu birds are slaughtered and dressed in similar manner to ostriches (Sales *et al*., 1997), and emus were previously slaughtered in Australia on conventional abattoir rails with manual removal of the feathers after bleeding (Tuckwell, 1993).

Kondjoyan *et al.,* (1993) found that emu meat as with other poultry meat, could be discriminated analytically on the basis of their volatile compounds. Emu meat is a relatively new product in US but has been proven a consumer favourite in Europe and is gaining acceptance in America as a gourmet product (American Emu Association News, 1994). Emu is a proven success in Australia, with a thriving commercial emu market. In 1994, 15 tonnes of emu meat from Australia were exported to France and the United States (US), Frapple, 1994).

Skadhuage *et al*., (1995) explained the low percentage of viscera in emus, in comparison to ostriches and rheas, owing to their anatomical differences, especially differences in the size of the colon (Swart *et al*., 1993).

The emu meat was found to have lower fat and calorie content than the beef, pork or chicken, but was similar to deer meat. Emu meat was found to have the highest sodium content at 80 mg / 3oz serving and the highest iron content at 4.6 mg / 3oz serving which was twice as much as that found in beef (2.36 mg / 3oz serving) by Daniel *et al*., 1997.

Berge *et al*., (1997) concluded that emu meat had similarities both with poultry meat and beef, with respect to rate of pH decline, time required for rigor onset, and complete meat tenderization, the emu meat behaved like conventional poultry meat.

The consumers rated M. iliofibularis as the most tender muscle in the emu. At present, there is no official distinction between the qualities of emu muscles. The entire emu carcass is used as whole meat cuts (Dingle, 1997).

Exotic meats are gaining popularity in the global meat market, where health – conscious consumers are becoming increasingly careful in choosing lean alternatives over traditional red meats (Daniel *et al*., 2000; Hoffman and Wiklund, 2006).

Among exotic meat species, ratites received significant attention as producers of low – fat meats (Andrews *et al*., 2000; Sales and Horbanczuk, 1998). The meat from ratites (i.e., ostrich, emu, rhea, cassowary and kiwi) is perceived and marketed as a healthy alternative to other red meats due to its leanness, low cholesterol content, and a favorable fatty acid profile.

Pegg *et al*., (2006), observed that the creatine level in fresh ground emu meat (695mg/100g) was lower than that in beef (786mg/100g). However, after thermal processing higher levels were detected in emu jerky (1,553mg/100g) than in beef jerky (1,518mg/100g). This demonstrates the potential of a processed emu meat snack to be considered as a

functional food for athletes looking for performance enhancement, and who are interested in consuming greater quantities of creatine from a natural food source.

Red meat in particular is recognized as a significant source of haem iron compared to poultry and fish (Johnston *et al*., 2007). Red meat is a nutrient rich food, supplying valuable amounts of protein, haem, iron, zinc selenium, B vitamins and retinol with increased bioavailability than found in other dietary sources (Cosgrove *et al*., 2005 and Davey *et al*., 2003). Lean red meat has been described as low in both saturated fatty acid and total fat (Li *et al*., 2005, and Williams, 2007).

Hoffmann, (2008) found that emu meat is usually sold as fresh meat and their trimmings being processed into products such as burger, patties and sausages. Most important micronutrients are best available from meat e.g., iron, selenium, vitamins A, B_{12} and folic acid either because they do not exist in plant – derived food or because they have poor bioavailability (Biesalski and Nohr, 2009).

2.2 Carcass characteristics

2.2.1 Live weight

Female emu attain a weight of 55 kg and height of 1.8 m, compared to 38 kg and 1.5 m, respectively, for males (Fowler, 1991). The body weights of emu have been reported to be about 40 kg at 64 weeks of age (Mannion *et al.*, 1995), 40.6 kg at 70 weeks of age (Frapple and Hagan, 1992) and approximately 55kg at maturity (Grzimek, 1972).

Body weight is a frequently recorded variable in animal research. It is the measurement most used to evaluate growth (Otte *et al*., 1992)

Sales *et al*., (1999) opined that a value of 34% on live weight basis for lean meat is lower than the 36% and 39% reported for ostriches (Morris *et al*., 1995) and rheas respectively.

Blood loss in emu was reported to vary from 1.8 to 7.6 % of live weight (Thompson *et al*., (1998).

2.2.2 Carcass weight

Jeffery (1998) reported that the average carcass weight of emu was approximately 37 kg with 54 % dress out. Approximately 60 % (12 kg) of the dressed weight was muscle and 40 % (8 kg) is fat.

Goonewardene *et al*., (2003) reported that as the average slaughter weight in emu industry was about 40 kg, it was evident that the emu were marketed when their growth efficiency was extremely poor. Therefore the emu industry should consider marketing emu at an earlier age.

Blake and Hess (2004) observed that the carcass weights for female emu were greater ($P<0.05$) than for males (23.17 kg vs 21.57 kg).

2.2.3 Dressing percentage

Morbidini *et al*., (1987), inferred that the carcass yield decreased at higher slaughter ages.

Tawfik *et al*., (1990) stated that age had a significant influence on dressing percentage. Emu are commonly slaughtered at 50 weeks, when the dressing percentage (cold carcass weight divided by live weight) is almost 70 % (Tuckwell, 1993).

Emu had the lowest percentage of hot carcass, wings, gizzard, viscera and liver to body weight in comparison to ostriches and rheas, which could be explained by the anatomical differences (Skadhauge *et al*., 1995).

Daniel, (1995) found that average dressing percentage of breeder quality emu was 48.87 %. This figure was considerably lower than the dressing percentage of ostrich, which is 58.9 % and cattle, which is approximately 63 % for prime and choice grades (Hedrick *et al*., 1994).

Sales *et al*., (1999) noted that an emu of 41kg body weight had a yield of 34% for total meat. Cifuni *et al*., (2000) observed that there was significant difference in the dressing percentage between age groups and the carcass yield decreased at higher slaughter ages. Blake and Hess (2004) reported that there were no significant differences in yield of fat and meat between males and females. They also concluded that carcass weights and yields were unaffected by feed treatment.

Reddy *et al*., (2007) observed that the dressing percentage of emu as percentage of live weight in their study was almost similar to values reported by Smetana (1993) in emu, but was slightly higher than the yield in ostrich, as was reported by Morris *et al*., (1995).

2.2.4 Chiller shrinkage

Sheridan *et al.,* (1998) found evaporative weight losses of 1.50% for rapidly chilled lamb carcasses compared to 1.89% for conventionally chilled lamb.

The conditions in which carcasses are kept after rapid chilling have a major impact on the appearance and weight loss of the carcasses. An equilibrium phase after rapid chilling is recommended (Bowater, 1986; McGeehin *et al.*, 1999).

Kandeepan *et al*., (2006) observed a significant chilling loss in stored buffalo meat.

The percent chiller shrinkage was observed to significantly increase with increase in age in buffaloes (Rao *et al*., 2009).

2.2.5 Meat: Bone ratio

Jones and Robertson, (1995) reported a lean : bone ratio of 3.48 and fat : bone ratio of 0.77 for culled emu.

The lean meat of emu on a hot carcass weight basis was 69 % in comparison to 63 % for ostrich and the lean meat on live weight basis of emu were lower (34 %) than ostrich (36 %) (Morris *et al*., 1995)

2.2.6 Yield of edible and inedible offals

Salem *et al*., (1983) found that weight of the head, hide and feet increased with age and thus reduced the dressing out percentage. They noticed that all the meat cuts did not show any significant change during the range of ages studied in buffaloes.

2.2.7 Carcass measurements

Dale and Bunnel (1984) published data on weights and measurements of captured Stone's sheep as part of a study on foraging behavior and nutrition and found that the chest girth is the best predictive equation for body weight and is applicable without seasonal variation.

Bundy *et al*., (1991) while working on 11 morphological measurements on carcasses of hunter killed white tailed deer (*Odocoeileus virginianus*) to predict their weight discovered that; chest girth was the best parameter for a predictive equation for live weight.

There is sometimes a need to estimate weight of animals and with the production of animals in remote areas where weighing scales are either unavailable or beyond the reach of the peasant farmer due to their prohibitive prices, it may even be essential to determine the weight of animals from easily measurable parameters, such as chest girth (Mayaka *et al*., 1995).

Heart girth is generally accepted as the single most reliable variable (Benyi, 1997) for growth. According to Heinrichs and Hargrove (1994) and Mulaudzi (2000) heart girth increases linearly with age in cattle. The positive correlation between heart girth and post-weaning growth rate indicates that selection for heart girth could possibly lead to faster growing animals (Fourie *et al*., 2002).

Maiwashe, (2000) stated that body size and body shape of animals can be described, using measurements and visual assessments. These measurements of size and shape are related to the functioning of the individual and is of paramount importance in livestock

production. Therefore, constant checks on the relationships between body measurements and performance traits are vital in selection programmes.

In a study on carcass characteristics of male Alpine kids, Anous and Mourad, (2001) observed that there was increase in carcass weights noticed with increase in Gigot length and Gigot width.

Studies on the correlation between carcass parameters and indirect measurements showed a high correlation between live weight and carcass lean content in poultry (Bochno *et al*., 1997, 1999 and Michalik *et al*., 2002).

Abdulrazaq *et al*., (2010) concluded that non invasive measurements allow indirect selection for carcass traits without slaughtering the birds.

In his study on *In vivo* prediction of live weight and carcass traits using body measurements in indigenous guinea fowl, Ogah, (2011) inferred that body weight, wing length and chest circumference had high positive and significant ($P<0.01$) correlation with carcass traits. He concluded that chest circumference had the highest predictive power in live weight estimate.

2.2.8 Carcass fabrication

According to the Australian Quarantine Inspection Services guidelines (AQIS, 1993), the emu carcass can be divided as stated: The carcass is split in two halves along the vertebral column into fore quarter and hind quarter. The forequarter is called the strip loin. The hind quarter is further divided into thigh and drum (having six muscles). The inside fillet of the thigh is removed to split the thigh into fore saddle and hind saddle (having four muscles each).

The information on emu fabrication is published in a manual entitled Register of Approved Emu Cuts and Items, developed by the Department of Agriculture, Western

Australia in conjunction with the Emu Farmers' Association of Australia (Inc.) and Australian Quarantine Inspection Service (AQIS, 1993).

Emu cuts include the fore saddle (fore rump, round, flat fillet, and oyster fillet), the hind saddle (hind rump, flat rump), fan fillet, and outside fillet) and the drum (inside drum, outside drum, mid drum, drum strap, inner mid drum, and inner outside drum). The fore rump and hind rump make up the full rump, which is the largest cut obtained from the emu. The full rump weighs approximately 0.81 kg. The full rump from a yearling bird of emu was approximately 4.36% of the carcass weight. The inside drum was the largest cut from the drum. (Frapple, 1994).

Hedrick *et al*., (1994) opined that it was extremely important for the meat industry to have uniform cut sizes inorder to predict cooking times, serving yields, serving size and the cost of the meat. They inferred that the size of cuts were largely governed by the size of the carcasses from which they are fabricated.

First grade wholesale cuts of lamb (rack, loin and leg) were not significantly affected by age at slaughter. Conversely as weight increased, percentage second grade cuts decreased (shoulder, neck and breast ($P<0.05$), Cifuni *et al*., 2000).

In both emu and ostrich, individual muscles are cut from the carcass and given separate identifying names and numbers (DAWA register of approved emu cuts and items; Mellet, F.D.1995). There is no breast meat and the majority of the meat comes from the legs and rump with smaller amounts from the back, ribs and the neck (Dingle, 1997).

2.3 Physico - chemical characteristics

2.3.1 pH

Kandasami (1983) observed that mean pH values of fresh and stored carabeef (72 hours) as 6.59 and 5.74, respectively. The variation in the changes in pH between fresh and stored carabeef were found to be highly significant.

Hoffman, (1988) stated that pH has a direct or indirect influence on the colour, tenderness, flavour and water holding properties of meat and in principle these also affect meat products.

Meat with a high ultimate pH (≥ 6.0) may be originated from stressed animal which might be deleterious to shelf life of meat products (Nortje *et al*., 1989).

The mean muscle pH value of 5.5 found in the emu (non-stressed) is lower than the values reported for the ostrich range 5.9-6.3; (Heinze *et al*., 1986; Morris *et al*., 1995; Sales, 1996). It is also lower than the values generally found in the breast or leg muscles of the conventional poultry species, viz.5.6-6.0 and 6.0-6.4, respectively (Touraille *et al*., 1981a).

Swan and Hall, (1995) indicated that the meat with high pH was darker, less red and less yellow than low pH meat. Meat pH can be affected by many factors; however, growth of lactic acid bacteria resulting in lactic acid production is the major factor in pH decrease in packaged meats (Gill, 1996).

Marsh *et al*., (1985) indicated that the rapid attainment of a low muscle pH would be beneficial towards meat tenderness, not only due to its prevention of cold-shortening, but also because it may cause the release of lysosomal enzymes and the activation of cathepsins. The juiciness or moisture holding capacity of the muscle is also greater at pH extremes than at pH 6 (Dingle, 1997).

Berge *et al*., (1997) observed that the pH of meat obtained from emus slaughtered after transport to an abattoir was found to be high, as with ostriches, but meat of normal pH (5.5-5.8) was obtained when stress before slaughter of birds was avoided. They also found that the mean muscle pH value of 5.5 found in the emu was lower than values reported for the ostrich (range 5.9-6.3; Heinze *et al*., 1986; Morris *et al*., 1995; Sales, 1996). They even recorded high final pH (6.1 reached 4-6 hours after bleeding) in emus that were electrically stunned immediately after arrival at abattoir. However, emus that were rested for two weeks

near the abattoir and were then transferred and stunned within 15 minutes had a final pH value of 5.6, 2-4 hours after bleeding.

The normal muscle pH profile of most red meat animals show a gradual decrease until an asymptotic minimum of about 5.4 to 5.5 has been reached, normally occurring over a 24hr period (Lawrie, 1998).

Similar to ostrich (Sales and Mellett, 1996) and rhea meat (Sales and Horbanczuk, 1998), relatively high final pH values (>6.0) that cause a dark colour, high water holding capacity and limited shelf – life in meat and is normally associated with pre – slaughtered stress, have been reported for emus that were slaughtered immediately up to arrival at the abattoir.

Richardson and Mead, (1999) reported that muscle pH and meat color are correlated, higher muscle pH is associated with darker meat whereas lower muscle pH values are associated with lighter meat.

Restructuring emu steaks with combinations of different binders (fibrinogen/ thrombin, algin/calcium lactate, phosphate/salt) resulted in higher pH values and cooked yields (Shao *et al*., 1999).

Richardson and Mead, (1999) reported that muscle pH and meat colour are correlated, higher muscle pH is associated with darker meat whereas lower muscle pH values are associated with lighter meat.

According to Warriss, (2000) acidification that occurs during conversion of muscle to meat is measured in terms of pH value which is inversely proportional to the concentration of lactic acid and thereby the initial glycogen concentration.

Raj *et al*., (2000) concluded that the delayed chilling resulted in a faster fall in pH and significant tenderization of excised buffalo muscles compared to direct chilling. The initial

pH of buffalo muscles decreased from 6.5 at 6 h and 5.6 at 24 h in direct chilling. The same initial pH (6.5) decreased to 5.65 at 6h and 5.5 at 24 h in delayed chilling.

Rao *et al*., (2009) reported a progressive fall in pH values of different age group means up to 48h of freezer storage and a slight increase in pH values at 7 days of freezer storage. No significant difference was observed in pH values between different age groups.

Lingaiah and Reddy, (2001) observed an increment in pH value in cooked products than that of raw products. They also noticed higher pH value in the products containing chicken meat and skin than that of the pH value of the product from chicken meat alone.

Reddy *et al*., (2004) observed that emu patties had a significant ($P < 0.05$) increase in mean pH values under refrigerated storage (4 ± 1^0c) up to 14 days.

pH decline rates in ostrich (Hoffmann and Fisher, 2001) and emu (Trout *et al*., 2000) muscles were such that toughening due to cold shortening or the effects of pale, soft, exudative conditions were eliminated.

Cremer and Chipley, (1997) reported an increase in pH during storage of pork patties attributed to proteolysis due to bacterial growth. Similar results were found by Thomas *et al*., (2006), Vijayakumar and Biswas, (2006), Reddy *et al*., (2004) and Ahamed *et al.*, (2007).

2.3.2 Water holding capacity

Water holding capacity of muscle is important because it affects both qualitative and quantitative aspects of meat and meat products. (Kauffman *et al*., 1986)

A large increase in water holding capacity could counteract the increased shear force value which was associated with the cold shortening of bovine and ovine muscle (Bouton *et al*., 1973).

Laborde and Monin, (1985) reported that the slow red muscle fibres had higher water holding capacity than the fast white muscle fibres.

An increase in water holding capacity is associated with a loosening of the network of the protein gel which results in an increase in tenderness (Lawrie, 1985).

The water holding capacity of meat is of great practical importance for meat processing and is affected by pH and the ion environment of the proteins. Because of high ATP levels and high pH, the slaughtered muscle which is still warm has a high water holding capacity, whereas post rigor meat, with low ATP and low pH, has a low water holding capacity (Honikel, 1987).

Many of the physical properties of meat (including colour, texture and firmness of raw meat, and tenderness, juiciness of cooked meat) are partially dependant on water holding capacity. Water holding capacity is defined as the ability of meat to retain its water during application of external forces such as cutting, heating, grinding or pressing (Hedrick *et al*., 1994).

Sharma and Sehgal, (1995) also reported that the lower water holding capacity is associated with higher ratio of moisture and protein in the meat.

One of the main quality attributes of fresh meat is its water – holding capacity because it influences consumer acceptance and the final weight of the product (Den Hertog – Meischke *et al*., 1997).

Approximate water holding capacity estimated by Ning Qiu, (1998), showed significant differences ($P<0.05$) across different raw emu cuts. The flat fillet had the highest approximate water holding capacity (23.87%), while the round had the least approximate water holding capacity (10.53%). He also concluded on further research that the approximate water holding capacity of raw emu meat negatively correlated ($P = 0.03$, R-sq = 72.8%) to the shear force values of cooked (at 65°C) emu meat.

According to Balog *et al*., (2006) muscle water content significantly influences meat tenderness.

2.3.3 Extract Release Volume (ERV)

The technique of ERV estimation was first described in 1964. It has been shown to be of value in determining incipient spoilage in meat as well as in predicting shelf life of meats stored under refrigeration (Jay, 1964b; Kontou *et al*., 1966; Pearson, 1968a).

Jay, (1964a) reported that fresh meat of good organoleptic quality released a large volume of ERV in a given period of time whereas, spoiled meat and protease treated beef homogenates released progressively less ERV or none.

Jay, (1964b) found highly significant correlation between bacterial numbers and ERV. He suggested that meat (ground beef) failing to produce an ERV of 25 – 30 ml should be regarded as spoiled, and he showed that this value corresponds to a bacterial load of about $10^{8.5}$/g.

Ingram and Dainty, (1971) suggested that the ERV value of about 30 given by Jay to discriminate between acceptable and spoiled meat was related to bacterial numbers and organoleptic characteristic associated with incipient spoilage and as such the predictive value of the test was little than other methods.

Both extract release volume (ERV) and pH rather than ERV alone may have to be considered for detecting the onset of spoilage of meat (Murthy and Bacchil, 1980).

Bacchil, (1982) observed that with the increase in pH and microbial counts there was decrease in ERV of stored fishes.

Rao and Sreenivasamurthy, (1986) stated that the microbial growth was reflected by changes in ERV and pH and in the spoiled meat, there was a decrease in ERV and an increase in pH value.

Regardless of the microbial quality of meat, the maximum ERV occurred at pH 5.5 in red meat (Warriss, 2000).

Reddy *et al*., (2007) concluded that contrary to the results of workers with chicken meat, the emu meat showed a significant ($P<0.05$) and gradual increase in ERV as the storage period increased.

2.3.4 R - value

The ratio of adenine nucleotidase to inosine nucleotidase (R-value) indirectly characterize the ATP level. The postmortem breakdown of adenosine nucleotidase to hypoxanthine derivatives takes about 12-24 hrs in normal muscle. This could be used as a method for determining the state of rigor mortis and an R-value higher than one indicates the beginning of rigor (Khan and Frey, 1971).

Papa and Fletcher, (1988) suggested that R-value indicates the onset of rigor at values between 1.00 and 1.10 corresponding to 75 to 85 % loss of ATP in the muscles.

An increasing trend in R- value indicated advancing rigor mortis development, finally reaching a plateau with maximum rigor mortis development (Sams and Mills, 1993).

Soares and Areas, (1995) inferred that changes in the postmortem ATP concentration could be effectively identified, by the (Inosine monophosphate) IMP/ATP ratio (R-value).

2.3.5 Fibre diameter

Tuma *et al.,* (1962) observed positive and significant correlation between shear force value and fibre diameter indicating that the larger the fibre diameter, the greater the shear force. They suggested that the effect of fibre diameter on tenderness appeared to be due to the animal age – fibre diameter relationship.

A trend towards larger fobre diameter was noted for the muscle fibres from the more mature carcasses which ranged from 64.02 to 69.01µm (Romans *et al*., (1965).

Herring *et al*., (1965) demonstrated that when muscles shorten, there was a corresponding decrease in sarcomere length and increase in fibre diameter which was accompanied by the decrease in tenderness.

Meister *et al*., (1974) found out that the muscle fibre diameter was inversely proportional to the number of muscle fibres.

Decrease in shear force value was related to a decrease in muscle fibre diameter and to increased tenderness (Locker, 1960; Berry *et al*., 1974; Hearene *et al*., 1978).

Singh *et al*., (1985) stated that in both breast and thigh muscles of layers the fibre diameter increased with age leading to increased toughness.

Siedeman *et al.,* (1988) concluded that a negative relationship exists between ultimate tenderness and cross sectional area of muscle.

Kandeepan *et al*., (2009) noted that fibre diameter was positively correlated to shear force values but negatively correlated to tenderness and sarcomere length of the muscle.

2.3.6 Sarcomere length

The sarcomere is the functional unit of the muscle and consisits of multinucleated cells that are bound together by an electrically charged plasma membrane (Stryer, 1988).

Marsh, (1985) demonstrated that muscles which shorten during rigor or were stretched (i.e., long sarcomeres) were more tender. The increase in concentration of free calcium in the presence of sufficient ATP results in increased shortening of the sarcomeres (Locker, 1985).

Thompson *et al*., (1987) reported 1.79 µm sarcomere length on broiler breast fillets, an average of 2.00 µm sarcomere length on the commercial pork loins was reported by Irving *et al*., (1989) and an average of 1.92 µm saarcomere length on unrestrained beef semitendinosus muscle was reported by Cross *et al.,* (1980).

Sarcomere length decreases with advancing age and increases the toughness of meat (Ffoulkes, 1992).

In mammalian muscle at rest, a sarcomere length of 2.5 μm is typical (Hedrick *et al*., 1994). If the muscle is relaxed when it enters rigor mortis (that is, the sarcomere unit is long, over 2 μm say, the meat is the most tender it could be (Dingle, 1997).

Ludwig *et al*., 1997 reported that after skeletal alteration (a pre rigor cut was made through the 12^{th} thoracic vertebra of one side of the beef carcasses (called tender cut) of longissimus muscle of beef, its sarcomere length was longer, and sensory panel ratings for myofibrillar tenderness, connective tissue and overall tenderness were higher, which indicated that this skeletal alteration technique increased tenderness.

Ning Qiu, B.S., (1998) observed that there was significant difference between the sarcomere lengths of different emu cuts. The flat fillet had the longest sarcomere (2.80 μm), while the round had the shortest (1.82 μm).

Variation in collagen proteolysis and sarcomere length and the degree of their interaction with one another determine the tenderness of individual muscle (Wheeler *et al.,* 1999).

2.3.7 Myofibrillar Fragmentation Index (MFI)

Myofibrillar fragmentation index (MFI) is an accurate index of meat tenderness. MFI correlates significantly with shear force values of cooked meat, though it is a measure of structural change in native myofibrils (Moller *et al*., 1973; Olson *et al*., 1976).

MFI is a useful indicator of the extent of proteolysis indicating both rupture of the I-band and breakage of inter-myofibril linkages (Taylor *et al*., 1995).

The contribution of MFI to tenderness was about 45% on the 1^{st} day of post-mortem but the concentration of MFI to tenderness at day 13 was substantially lower: 26% for shear force and 19% for sensory tenderness (Silva *et al*., 1999).

Studies underwent by Birkhold and Sams, (1993), indicated that electrical stimulation / muscle tensioning treated carcasses exhibited less Myofibrillar fragmentation index than carcasses treated with muscle tensioning only.

It was shown by Hopkins *et al*., (2000) that as the speed of homogenization increased up to 15,000 rpm, the rate of change in MFI values decreased.

The impact of the speed of homogenization and the state of the sample on the MFI had been examined recently by Hopkins *et al*., (2000); Veiseth *et al.,* (2001).

Recently a new approach to examine Myofibrillar degradation was proposed by Lametsch *et al*., (2007), using laser diffraction to measure particle size based on the principles of the Mie theory of light scattering.

Kandeepan *et al*., (2009), found that MFI and shear force value were negatively correlated in their study on the effect of age and gender on the processing characteristics of buffalo meat.

Karumendu *et al*., (2009) in their findings, depicted that correlations between particle size and shear force were found to be low (0.23) and even lower than that reported by Lametsch *et al.,* (2007).

2.3.8 Shear force value

An example of an objective measuring device that can be used on meats is the Warner-Bratzler shear press. This instrument measures the force required to cleave a cross-sectional sampIe of cooked meat across the muscle fibers (McWilliams, 1989).

Akinwunmi *et al*., (1993) reported that the mean shear force value for the cooked beef steaks from loins of carcasses was 59.8N; while Lyon and Lyon, (1997) recorded that the shear value of deboned poultry (both left and right breast fillet strips) after 24 hrs postmortem was 33.9 N; and Thompson *et al*., (1987) reported 41.3N shear value on broiler chicken breast

fillets. From those data, chicken breast meat appeared to be tenderer than beef loin, but was not as tender as emu flat fillet and fan fillet.

A study completed on beef in a retail environment by Huffman *et al*., (1994) found the tenderness threshold to be between shear values of 4.1 kg to 4.3 kg. A shear value over 4.3 kg was considered by the consumers to be slightly to extremely tough and values below 4.1 kg were considered slightly to extremely tender.

Numerous devices have been tested for their ability to measure meat tenderness. The device most often used to measure meat tenderness (because it is most consistently highly related to sensory tenderness rating) is Warner Bratzler shear force (AMSA, 1995).

Thompson *et al*, 1995, observed a wide variation in the mean (SE) Warner Bratzler shear force values between muscles in emus [4.4 (0.97)] kg and Ostriches [3.4 (1.08)] kg. (Sales, 1996).

Daniel, (1995) found that the rump of emu was slightly tender (5.8) at 60°C; however, as the temperature increased to 66°C, the rating dropped to slightly tough (4.9). Tenderness continued to decrease as the temperature increased to 75°C, causing the rump to become moderately tough (3.7).

Wheeler *et al*., (1996) stated that critical control points for measurement of shear force include steak temperature at the initiation cooking losses and shearing instrument standardization.

Ning Qiu, (1998) observed in his studies that the mean Warner – Bratzler shear force values showed significant differences ($P<0.05$) across cooked emu cuts. The round had the highest shear force value 61.0N, while flat fillet had the lowest with 24.5N. The full rump was intermediate in shear force value with a mean of 45.8N, which was also significantly different from either round or flat fillet.

Fiems *et al*., (2000) studied the relationship between the shear force value and the lightness of the meat and fat characteristics and observed that they had limited predictiveness on meat colour.

Reddy *et al*., (2007) found that the mean shear force values found in emu meat were comparable to the results of Sales (1996) in emu.

2.3.9 Collagen content

Miller *et al*., (1983) concluded that the total collagen content in both young and mature steers were found to be 11.0 and 12.6 mg/g, respectively.

With an increase in animal age, the collagen content remains constant within each muscle, but the heat stability of this component increases due to the formation of nonreducible links between chains, which results in increased tensile strength (Lawrie, 1991).

An age related increase in pyridinoline content of intramuscular collagen and cross link formation influenced by sex contributed to the toughness of meat in spent groups (Bosselmann, *et al*., 1995).

As animals get older the collagen cross links become stabilized and the collagen is much less soluble (Maltin *et al*., 1998).

Field *et al*., (1996) found a negative correlation between collagen characteristics and measures of tenderness.

Berge *et al*., (1997) reported that the emu muscle contained less collagen (6mg/g) than the chicken leg muscle (Culioli *et al*., 1990) and in this respect, its composition was comparable to that of the breast muscle of chicken and to that of the ostrich muscle. They also found that tenderness of the different muscles increased in the order of their decreasing total collagen contents, and the major factors of toughness of emu meat, when cooked to 60ºc, were the content and heat stability of the intramuscular connective tissue.

Dingle, (1997) found that the muscles of emu in front of the thigh (the quadriceps group and the back of the lower leg (the gastrocnemius group) appear to be used more in locomotion as they are usually tougher and have more connective tissue than rump muscles and inside loin muscles.

Ning Qiu, (1998) observed that there was significant difference in the collagen content across different emu muscle types. For instance, the round had the highest value of collagen content (8.33 mg/g), while the flat fillet had the least (4.69 mg/g).

Palka, (2003) observed increase in quantity of soluble collagen in meat roasted to an internal temperature of 80°C as compared to its quantity in the raw material.

Obuz *et al*., (2003) stated that the changes in meat tenderness with cooking result from alterations in connective tissue and Myofibrillar proteins.

Tenderness decreases with increase in age of the animal due to higher collagen content and formation of stable collagen cross – links (Murthy and Devadason, 2003).

Collagen density within the superficial dense connective tissue layers of the dermis was highest in female emus (Weir and Lunam, 2004).

Kandeepan *et al*., (2009), observed that the collagen content of meat from intensively reared young male buffaloes was significantly ($P<0.01$) lower than the other two groups.

2.3.10 Texture profile analysis

Texture profile parameters were determined following descriptions by Bourne, (1978) and interpreted as follows, Hardness (kg) is the maximum force required to compress the sample: Cohesiveness is the extent to which the sample could be deformed prior to rupture (A_2/A_1), A1 being the total energy required for the first compression and A_2 the total energy required for the second compression; Springiness total energy required for the sample to recover its original shape (cm) is the ability of the sample to recover its original shape after the deforming force is removed; Gumminess (kg) is the force to disintegrate a semisolid meat

sample for swallowing (hardness × cohesiveness) and Chewiness (kg × cm) is the work needed to masticate the sample for swallowing (springiness × gumminess).

Mittal *et al*., (1992) found that the TPA parameters were modified by dividing with sample cross section area and strain. He also added that the recommended test conditions are D/L = 1.5, compression ratio =75% and rate of compression =1 – 2 cm/min.

Cavestanty *et al*., (1994) reported that the variations in textural properties of meat and meat products may be influenced by a variety of factors such as differences in formulation and ionic strength, functionality of meat proteins, concentration and characteristics of fat and others.

Cohesiveness refers to the strength of internal bands making up the body of the product (Giese, 1995).

Sczezesniak, (2002) defines texture as "a sensory and functional manifestation of the structural, mechanical and surface properties of foods deducted through the senses of vision, hearing, touch and kinesthetics.

In texture profile analysis, parameters indicated by hardness and adhesiveness could be useful in explaining a significant proportion of variation in tenderness of rib steaks. Juiciness, flavor desirability and flavor intensity were not well correlated with TPA parameters. Springiness and resilience might be highly related to intramuscular fat content, which in turn is a determining factor in juiciness and flavor desirability (Caine *et al*., 2003).

Han – Jun Ma and Ledward, (2004) analysed texture profile of beef longissimus dorsi muscle to high pressure treatment and reported a decrease in hardness with increase in temperature and pressure.

Thomas *et al.,* (2006) concluded that the texture profile of buffalo meat nuggets had higher significant cohesiveness, gumminess, chewiness and shear force values.

2.3.11 Thiobarbituric acid number

Melton, (1983) stated that 2- thiobarbituric acid (TBA) method with its different variations was the most widely used test for measuring the extent of lipid oxidation in muscle foods.

Products of lipid oxidation have been associated with off – flavours and off – odours, loss of colour and ultimately may also affect the safety of meat (Pearson *et al*., 1983).

Kandasami (1983) stated that the ERV of fresh carabeef ranged from 24 ml to 44 ml with mean of 33.23±1.05 ml and in carabeef stored at 5 ± 1 ^{0}C for 72 hr, it ranges from 18 ml to 39 ml with mean of 28.88 ±1.99 ml

Hollender *et al*. (1987) reported that TBA (Thiobarbituric acid) values generally increased during storage.

Arif *et al*. (1993) observed that TBA value of meat increased with increase in either refrigerated of frozen storage period.

Raharjo and Sofos, (1993) noted that the 2-thiobarbituric acid (TBA) method was the most widely used test for measuring the extent of lipid peroxidation in red meat and poultry, due to its speed and simplicity.

Kanner, (1994) reported that lipid oxidation was the major chemical reaction that deteriorates physico-chemical characters viz., flavor, colour, texture, and nutritional value of muscle foods.

Shahidi, (1994) stated that lipid oxidation was considered as the primary cause of flavor deterioration due to the development of oxidized flavors (“warmed-over flavor”) in cooked, stored chicken meat products.

The TBA test has been widely used to measure lipid oxidation in meat and meat products. Lipid oxidation is a significant problem related to the off – odour development in meat (Fernandez *et al*., 1997).

Lipid oxidation, particularly oxidation of phospholipids limited the keeping quality of meat and meat products of pre – cooked meat due to the development of unacceptable warmed over flavor by auto – oxidation process (Sahoo and Verma, 1999).

Lipid peroxidation is one of the major causes of quality deterioration in raw and cooked meat products during refrigerated or frozen storage. The TBA values tended to decrease ($P<0.01$) as age at slaughter increased. (G.F. Cifuni, *et al.,* 2000).

Gomes *et al*., (2003) opined that lipid peroxidation was one of the major causes of quality deterioration in raw and cooked meat products during refrigerated and frozen storage.

Reddy *et al*., (2004) observed progressive increase in TBA values up to 42 days. They also found progressively significant ($P <0.05$) increase in thiobarbituric acid (TBA) values of emu patties under refrigerated (4±1° C) storage condition up to 42 days. Similar results were obtained by Brewer *et al*., (1997) in beef patties.

2.3.12 Tyrosine value

Pearson, (1968) demonstrated that tyrosine value of meat increased with storage along with total volatile nitrogen.

Strange *et al*., (1977) noted that tyrosine value increased with microbial growth (0.46mg at $10^4/cm^2$ and 0.73mg/g at $10^8/cm^2$) during spoilage of meat. They also observed that the tyrosine levels were influenced by the bacterial population as well as by the duration of storage of meat samples.

Kulkarni *et al*., (1993) reported that the tyrosine value of stored buffalo meat sausages increased during storage.

Jay, (1996) stated that tyrosine value had been used as one of the methods for detecting microbial spoilage in meats, poultry and sea foods.

Vijayakumar and Biswas, (2006) found highly significant increase in tyrosine value in duck cutlet with increase in storage period under refrigerated (4 ± 1°C) temperature.

Ahamed *et al*., (2007) found that tyrosine value of buffalo meat cutlet increased significantly ($P<0.05$) with increasing storage period upto 10^{th} day under refrigerated (4 ± 1°C) temperature.

Manimaran, (2007) reported a progressive increase in tyrosine value buffalo meat sausage during refrigerated storage.

2.3.13 Myoglobin content

According to Livingston and Brown, (1981). Myoglobin is the main pigment responsible for meat colour and the form that this protein takes in these muscle foods is of prime importance in determining the colour of the product, which is one of the main quality indices of importance to the consumer. The myoglobin concentration of muscle varies between and within species and is affected by factors such as age, exercise and diet of the animal, as well as genetic and environmental factors.

Factors which influence oxygenation of myoglobin are concentration of the pigment, temperature, relative humidity and biological agents. Pigmentation depends on some factors as species, breed, age, feeding, muscular activity and pH (Forrest *et al*., 1975; Mac Dougal, 1977; Nottingham, 1982).

In red meats oxy myoglobin imparts the colour that consumers associate with freshness (Faustman and Cassens, 1990). Myoglobin is purplish red in colour and is

responsible for the colour of meat immediately after cutting into a deep muscle, or of meat stored under vaccum (Renerre, 1990).

Myoglobin can exist in one of three forms: deoxymyoglobin, oxymyoglobin or metmyoglobin. Interconversion of the three pigment states is possible and the dominant pigment form depends on localized conditions (Kropf, 1993).

On comparison, the breast muscle of a chicken was light and the leg and thigh muscles were dark due to more myoglobin (Hedrick *et al*., 1994).

Myoglobin is the sarcoplasmic heme protein primarily responsible for the red colour of meat from animals and birds. In live animals, myoglobin serves both oxygen – storage and oxygen – delivery functions in skeletal muscles (Wittenberg and Wittenberg, 2003).

The primary structure of myoglobin influences several of its physiological functions such as auto oxidation (Tada *et al*., 1998; Stewart *et al*., 2004), heme retention (Greenwald and Richards, 2006), structural stability (Regis *et al*., 2005), thermo stability (Ueki, Chow and Ochiai, 2005; Ueki and Ochiai, 2006), and oxygen affinity (Enoki *et al*., 1995); Marcinek *et al*., 2001).

The observed molecular mass of singly protonated ion of emu Mb in the MALDI – TOF mass spectra (17, 380 Da) was close to the calculated molecular mass (17, 376 Da) based on amino acid sequence (Gasteiger *et al*., 2005).

Suman *et al*., (2010) demonstrated that emu myoglobin's molecular mass was 400 – 450 Da greater than those of well – characterized livestock species such as cattle, buffalo, horse, sheep, goat and pig.

2.3.14 Spectrophotometric Assay of meat colour

The colour of fresh meat is an important attribute for the consumer and the temperature at which muscles enter into rigor during the conversion of muscles to meat affects meat colour (Hood, 1980).

According to Livingston and Brown, (1981) myoglobin is the main pigment responsible for meat colour and the form that this protein takes in these muscle foods is of prime importance to the main quality indices of importance to the consumer.

Three factors are responsible for meat colour- physical structure of the meat, pigment concentration and the chemical state of the pigments (Mac Dougall, 1983).

Meat colour has decisive influence on consumer's selection, and tender, juicy meat usually leads to consumer's continuing purchases (Lawrie, 1985).

In general it includes colour, texture, tenderness, flavor and juiciness. Among these attributes, it is only the colour of meat that determines the consumer's acceptance of the product, the rest being perceived by human palate at later stage (Mohan Raj, 1988).

Dietzel *et al*., (1990) observed that the chroma (intensity of colour) and hue value (colour) of emu meat were less intense in redness and more purple than beef and venison (Stevenson *et al.,* 1989).

Lightness in meat and meat products depends on several factors like water holding capacity (Fernandez, *et al*., 2000: Kauffman, *et al*., 1991), fat content (Fischer *et al*., 2000), free water (Judge, *et al*., 1989), etc.

In red meat oxymyoglobin imparts the colour that consumers associate with freshness (Faustman and Cassens, 1990). Johnson, *et al*., (1991) suggested that the a* coordinate is related to the myoglobin content. Patak and Baldwin, (1993) found high concentrations of haem pigment (29µg fe/g) in the muscles of emu.

An attractive bright red colour is compatible with long shelf life and eating quality (Hood and Mead, 1993).

Meat colour is dependant on the concentration and chemical state of the meat pigments, primarily myoglobin and haemoglobin, and on the physical characteristics of meat such as its light scattering and observing properties (Kropf, 1993).

Risvik, (1994) stated that preference for meat seemed to be most strongly effected by changes in colour /appreance and texture and to a lesser extent by flavour changes.

Joo *et al*., (1995) noticed that there were highly significant correlation between the measures of colour and pH.

In the studies reported by Dingle *et al*., (1995) there were no or few significant differences in the objective evaluation of different emu muscles. In the studies reported by Mann *et al*., 1995, there were small, but significant, differences in the subjective evaluation of muscle colour, the brightest red colour being the M. Iliotibialis cranialis and the darkest, M.Iliofemoralis on a 1to8 scale of bright cherry red to very dark colour.

In the case of fresh red meat, two important visual clues that determine perceived quality are colour and packaging (Issanchou, 1996).

The red colour of emu meat can be partly explained by the high pigment content-26µg Fe/g Fresh emu meat has a low colour stability. This together with intramuscular lipids that oxidize very rapidly, complicate assurance of consumer acceptability after a period of more than 3 days of retail display in contact with air (Berge *et al*., 1997).

Pietrasik, (1999) reported that a reduction in the fat level generally favours the appearance of darker colourings. The redness (a*) values were inversely proportional to fat content and strongly depend on protein level. Reduced protein content resulted in dilution of myoglobin and consequentlyless red colour in meat.

Fletcher *et al*., (2000) stated that cooked chicken nuggets were lighter in colour and less red than the raw emulsion, similar to that of breast poultry cooking.

Fiems *et al*., (2000) studied the relationships between the shear force value and the lightness of the meat and fat characteristics. They observed that the fat characteristics of the carcass and meat showed only limited predictive power for meat colour. They also observed that the fat characteristics of the carcass and meat showed only limited predictive power for meat colour.

Hoffman and Fisher, (2001) observed that older ostriches had significantly lower reflectance (L*) values ($P<0.001$) and higher a* ($P<0.001$) and b* values ($P<0.05$) compared with the 14 month old birds.

The evolution of redness is related with lipid oxidation in meat products (Fernandez – Lopez *et al*., 2003; Yu, *et al*., 2002). Increase in fat and/or water in meat results in lighter products (Littinandana *et al.,* 2005).

Perlo *et al*., (2006) found significant difference ($P<0.05$) in L*, a* and b* values with different proportions of mechanically deboned chicken meat.

Abdullah, (2007) reported that higher the lean meat content, higher was the colour of the canned luncheon meat.

Suman *et al*., (2010) also observed that Emu meat is darker in colour compared to poultry meat due to increased myoglobin content. Thus, colour of emu meat is similar to red meats harvested from livestock.

Consumers considered surface colour as contributing factor to acceptability of marinated chicken to a greater degree compared to colour penetration (Yusop *et al*., 2010)

Pakula and Stamminger, (2012) noticed that consumers and cooks often assess the degree of doneness (75°C) of roasted beef by the internal meat colour.

2.3.15 Drip loss

The amount of drip in cut meat is also largely dependent on sample thickness, surface to volume ratio, orientation of cut surface with respect to muscle fibre axis and prevalence of large blood vessels (Farouk *et al.,* 1990).

Drip loss is thought to originate from the spaces between fibre bundles and the perimyseal network and additionally, the spaces between muscle fibres and the endomysial network (Offer and Cousins, 1992).

Petrovic *et al.,* (1993) stated that there are numerous factors that influence the quality of drip loss indicated that drip losses during thawing are lower if the freezing rate is faster at temperatures below the eutectic point (< -70^{o}C).

Van der wal *et al*., (1995) observed a drip loss in buffalo *longissimus lumborum* as 3.9% in conventional chilling when meat was nearer to ultimate pH.

Factors, which may affect drip losses include; rigor temperature and membrane integrity (Honikel *et al*., 1986) preslaughter stress, processing factors and packaging (Payne *et al*., 1997).

2.3.16 Cooking loss

The effect of cooking temperature would result in myofibrillar hardening produced by increased cooking losses and increased myofibrillar contraction (Draudt, 1972).

Petrovic *et al*., (1993), showed that when meat was frozen at temperatures below the eutectic point (-70ºc or lower) there was a significant disturbance of muscle ultra structure and an adverse effect on the quality of the frozen meat resulting in higher cooking losses in meat.

When muscle is subjected to heating, coagulation of proteins and thermal shrinkage of meat takes place resulting in the release of meat juices (Ziauddin *et al*., 1994).

Daniel, (1995) reported that there were no significant differences between emu muscles for cooking losses. There were significant increases in cooking losses as temperature increased.

Miller and Holben, (1999) opined that fat might have involved in the higher cooking loss in beef patties than patties made from emu meat.

Hoffman and Fisher, (2001) found that the comparison of cooking loss values did not suggest large differences between the two age groups of ostriches.

Lawrence *et al*., (2001) suggested the cause of increased cooking losses to be shortening of sarcomeres and collagen shrinkage, which forces out fluids.

2.4 Nutritional Quality

2.4.1 Proximate composition

A report conducted by the Roper Organisation, Inc. (1992) found that seven out of ten consumers rely heavily on nutrition information and 87% of purchasing decisions are influenced by nutrition labels.

Strategies for the introduction of new products must focus on the superior quality of the meat, both from the nutritional perspective and in terms of texture, which are determined by the meat chemical composition (Jones *et al*., 1994; Sales, 1997).

The perceived healthiness of a food is of great importance for consumer preference (Fisher *et al*., 2000). The chemical composition of meat is influenced by nutrition (Van Schalkwyk *et al*., 2002; Hoffman and Mellet, 2003; Lanza *et al*., 2004; Van Schalkwyk *et al*., 2005), particularly by the energy:protein ratio (Van Schalkwyk *et al*., 2002), and energy is mainly responsible for the carcass fatty acid profile (Lanza *et al*., 2004).

Moisture

D. R. Daniel, (1995) compared raw emu with beef, chicken and deer and found that the moisture content of emu was maximum (74.10%) and that of beef minimum (70.27%).

Sales, (1997) noted that cooking led to a decrease in moisture content (with a concomitant increase in the other constituents) in ostrich meat.

Protein

According to a nutritional comparison study by Frapple, (1994) emu meat (thigh) had 1.7 – 4% fat, 113 – 127 Kcal/100g and 21.2% protein, which was comparable to chicken breast (flesh only, broilers – fryers) and turkey (flesh only, broilers – fryers). The cholesterol content was 39 – 48 mg/100 grams. The iron content of emu meat was 5 mg/100g (Silliker Laboratories, 1994). This level is almost approaching beef liver which is 6.82 mg/100g (USDA, 1990).

Berge *et al*., (1997) observed that the mean moisture and protein content of emu meat was (754 and 210g/kg respectively) and were similar to those generally found in muscles of ostrich, (Sales, 1996).

Of the meat from deer, ostrich, emu, bison, cattle, turkey and elk reported in the University of Wisconsin – Madison study (2000), emu meat was found to be the richest source of protein and haeme iron (5.0 – 3.4 mg iron/100gm of cooked product for both venison and ostrich meat).

Karthick, (2012) reported that protein was found to be higher in emu cutlet since emu meat was known to be lean meat with low fat.

Fat

Reddy & Reddy, (1990), noticed that in duck the percent ether extract of both breast and thigh muscles increased with age.

The emu muscles contained, on an average, less lipids (10g/kg) and less collagen (6g/kg) than the chicken leg muscles and in this respect, their composition was comparable to that of the breast muscle of chicken (Touraille *et al*., 1981b ; Culioli *et al*., 1990; Smith *et al*., 1993; and Xiong *et al*., 1993).

The emu meat was found to have lower fat and calorie content than the beef, pork or chicken, but was similar to deer meat (Daniel *et al*., 1997)

Total Ash

Sales and Hayes, (1996) compared the proximate composition of ostrich meat to that of beef and chicken and found that the ash contents and protein were constant between species.

2.4.2 Mineral content

Campbell and Anderson, (1987) discovered that zinc, along with chromium and copper, were found to be excreted in large amounts when people exercise rather than when people are sedentary. Evidently, the inside drum of emu gets extensively more exercise, there is significantly increased concentration of zinc in that particular muscle The zinc content was 3.65 mg/100g for the inside drum and 3.17mg/100g for the full rump (D. R. Daniel, 1995).

Pegg *et al.,* (2006) estimated the mineral composition of emu meat and found that there were no barium, beryllium, cadmium, lead, molybdenum, nickel, silver, titanium, vanadium or zirconium could be detected.

Ning Qiu, (1998) observed that there was significantly higher sodium in the outside fillet (89.94 mg/100g) than the flat fillet (88.19 mg/100g) and as for the calcium and potassium, the round had the lowest amounts (4.83mg/100g for Ca and 314.8 mg/100g for K).

2.4.3 Cholesterol content

Knowledge about the cholesterol content and fatty acid composition of food will serve not only as a reliable standard of reference to all concerned with the nutrient content of food, but also provide a valuable tool for those engaged in research on the possible relevance of dietary lipids to heart disease and arteriosclerosis (Weihrauch *et al*., 1977).

Hoelscher *et al*., (1988), came to the conclusion that cholesterol content does not increase with an increase in intramuscular fat content. Differences occur in the subcellular distribution of cholesterol in muscle tissue as intramuscular fat content.

Frapple, (1994) showed raw emu as having a cholesterol content of 39 – 48 mg/100g. As a consequence of low fat content, the cholesterol content is also lower in emu meat than in the meat of other domestic animals like ostrich, deer, pork, beef, poultry and fish compared by Dingle, 1997.

The cholesterol content of meat of emu were less than that in meats of ostriches, which ranged from 56.6 to 71.2 mg/100g of meat from six different muscles (Sales, 1998; Sales and Horbanczuk, 1998, L. M. Beckerbauer *et al.,* 2001). It was found in their studies that the cholesterol content of emu meat was 32.2mg/100g of meat and the cholesterol concentration of emu oil was not affected by the diet but dependant on the tissue from which it was derived.

Cholesterol content reported for raw emu meat varies from 32.2 (Beckerbauer *et al*., 2001) to 98.0 mg/100g (Daniel *et al*., 2000) and differences are probably related to techniques to quantify cholesterol among laboratories.

Girolami *et al*., (2003) found that cholesterol, differently from fatty acids, does not change according to age at slaughter.

2.4.4 Fatty acid profile

Factors such as sex, live weight, breed type, feeding regime, hormones, dietary fat and age have been related to fatty acid composition (Kemp *et al*., 1981).

Major fatty acids in meat include: SFA – myristic (14:0), palmitic (16:0) and stearic (18:0); MUFA – Palmitoleic (16:0) and oleic (18:1) and PUFA- linoleic (18:2), Linolenic (18:3) and arachidonic (20:4).SFA and MUFA constitute the majority of the fatty acids in meat fat (Dugan, 1987).

Rhee, (1992) found that fatty acids composition of meat products was an important health concern to consumer. It is also a primary factor that determines the flavor and storage shelf life. Despite the common reference to animal fats as "saturated", less than half of all fatty acids of meats are saturated.

Wang *et al*., (2000) opined that due to the positive association between animal fats and certain diseases (such as coronary heart disease, atherosclerosis and cancer) (Simopoulos, 1991; Fernandes and Venkataraman, 1993), the consumers of today are searching for food items with higher levels of health – enhancing fatty acids. Therefore, further understanding of the lipid characteristics of emu meat and edible tissues could make the industry grow at even faster rate (Craig – Schmidt *et al*., 1994) and may create niche markets.

The major MUFA in emu was oleic acid and comprised over 50% of the total fatty acids. It was reported that oleic acid can enhance penetration of biologically active compounds that have been proven to be beneficial to the skin, thus has been widely used as a carrier based in cosmetic industry. (Frapple, 1992).

Tuckwell *et al*., (1993) reported higher content of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in emu meat when compared to chicken and beef meat.

A higher poly unsaturated to saturated ratio of 0.9 has been reported for emu meat by Mann *et al*., (1995). The fatty acid composition of meat will vary by animal age, sex, breed, diet and within the act of meat (Wood & Enser, 1997).

Emu meat contains similar concentrations of palmitic, palmitoleic and linolenic acids, less amounts of stearic acid and the poly unsaturated 20 and 22 carbon fatty acids; and greater amounts of oleic and linoleic acids than similar cuts of meat from African Black Ostriches of 8 to 14 months of age (Sales, 1998).

Oleic acid (C18:1 n-9) was the predominant MUFA (48%) in emu meat. The emu drumstick contained higher ($P<0.05$) linoleic (C18:2 n-6), arachidonic (C20:4 n-6), linolenic (C18:3 n-3) and docosahexanoic (C22:6 n-3) acids than chicken drumstick and beef steak. The ratio of polyunsaturated fatty acids to saturated fatty acids in emu meat was 0.72, higher ($p< 0.0001$) than chicken meat, 0.57 and beef meat, 0.3 (Wang *et al*., 2000).

The saturated palmitic (C16 : 0) and heptadecanoic (C17 : 0) fatty acids content in lambs increased as age at slaughter increased ($P<0.01$), whereas the unsaturated myristoleic (C14 : 1), 9 heptadecanoic (C17 : 1) and linolenic and (C18 : 3) contents decreased ($P<0.05$), Cifuni.*et. al*., (2000).

Wang *et al.,* (2000) conducted recurrent studies and found that the ratio of n-6 to n-3 fatty acids in emu fat was 6:1 and was within the range (4:1to 10:1). as recommended by the Health and Welfare, Canada (1990) for human health.

Nutritionists are recently focusing on the type of PUFA and the balance in the diet between n – 3 PUFA formed from α-linolenic acid (18:3) and n-6 PUFA formed from linoleic acid (18:2) (Williams, 2000). These two poly unsaturated fatty acids (PUFAs), namely linoleic acid and α - linolenic acid, cannot be synthesized from mammalian tissues and are therefore essential micro nutrients (Minihane, 2006)

Beckerbauer *et al*., (2001) concluded that emu meat was low in fat (2.2%) and low in cholesterol (32.2mg/100g of tissue) relative to other commonly consumed meats, except for white meat of chickens and turkeys. They also observed that the major saturated fatty acid in emu meat was palmitic acid (16:0) at 19.6%, the major mono unsaturated fatty acid was oleic

acid (18:1) at 41.1% and the major poly unsaturated fatty acid (PUFA) was linoleic acid at 23.5%, Palmitoleic acid (16:1) averaged 3.8%, stearic acid (18:0) 10.0% and linolenic acid (18.3) 15%. They even noted that the fatty acid profile of emu meat was influenced by the diet.

Hoffman and Fisher, (2001) observed that there was a concommitant decrease in the percentage of 20:5 omega 3, 22:5 omega 3, ± and 22:6 omega 3 fatty acids with an increase in age of ostrich meat.

Sabbioni *et al*., (2003) did not find any differences in lipid, cholesterol and fatty acid content in different ostrich muscles. The meat of young ostrich birds usually presents lower lipid levels as compared to older ones. However, some researchers (Hoffman and Fisher, 2001; Girolami *et al*., 2003; Sabbioni *et al*., 2003) studied lipid content in the carcasses of birds slaughtered at different ages and did not find significant differences as to lipid content, but differences in lipid quality.

Consumption of meat containing high amounts of poly unsaturated fatty acids (PUFAs) has greatly increased in the last decade keeping in view the nutritionists recommendations to reduce intake of saturated fatty acids. High content of unsaturated fatty acids in diet may cause lipid oxidation which creates a risk to human health because of the possible formation of atherogenic, mutagenic and cytotoxic compounds (Fernandez *et al*., 2005).

The main fatty acids in broiler breast and thigh tissues were oleic acid, palmitic acid, linoloeic acid and stearic acid. Its Fatty acid profile is highly dependant on the dietary source (Royan, 2012).

Under various production and processing conditions, greater variability in fatty acid composition of lean meat products were observed when compared with ground meat products (Colmenero *et al*., 2010)

2.4.5 Amino acid analysis

The findings of Schweigert, (1987) reveals that the protein content as well as the amino acid composition of the protein remains remarkably constant independent of the cut.

Ziauddin *et al*., (1994) studied the physicochemical characteristics of buffalo meat and observed a high concentration of lysine and lower content of amino acids such as phenylalanine, tyrosine, isoleucine and tryptophan in it.

Sales and Hayes, (1996) compared the amino acid composition of ostrich to that of beef and chicken and found that ostrich meat was higher in phenylalanine and lower in histidine than either beef or chicken and intermediate with regard to valine, methionine, isoleucine and leucine.

Chandrasekharaiah *et al*., (2003) measured the essential amino acids in food and feed stuff under high pressure liquid chromatography (HPLC) using pre – column derivatisation with phenyl iso – thiocyanate.

Storksdieck *et al*., (2007) concluded that the peptides responsible for "meat factor" have enriched with aspartic and glutamic acid and possibly originated from myosin.

Suman *et al*., (2010) found that amino acids sequence of emu myoglobin was different from those of other ratites and red meat producing livestock. On comparison of amino acid sequence they found that emu Myoglobin shared greater homology with ostrich myoglobin than with other ratites and meat producing livestock.

2.5 Microbiological quality

It is very difficult to develop common quality standards for the meat market as meat quality concept is changing significantly over time *(*Frisby *et al.,* 2005*;* Bogosavljevic - Boskovic*,* 2007*)*.

2.5.1 Total plate count

International Commission on Microbiological Specification for Food (ICMSF, 1974) recommended that the total viable count at 35°C should be less than $10^{7/}$ g.

The bacteriological standard proposed for dried meat was 10^5/g (total count) (Skovgaard, 1969).

Bacterial numbers of $\log_{10}$ 3.0 cfu/cm^2, may be regarded as an indicator for good hygiene and efficient commercial operation (Sheridan and lynch, 1979).

Mrigadat *et al*., (1980) used plate count method for determining aerobic plate counts at 25^o c for 3 days in beef and lamb.

Newton and Gill, (1980) stated that growth rates of all meat spoilage bacteria would be similarly reduced because of low pH meat.

Aerobic plate count (APC) or Standard plate count (SPC) has been used as criterion for predicting shelf life and assessing the hygienic standards of poultry processing plants (Lillard *et al*., 1984) and for evaluating the microbial quality of foods (Miskimin *et al*., 1976). The SPC is by far the most widely used method for determining the members of colony forming units in food products (Jay, 1996).

Increase in microbial counts in products with increase in storage period at refrigerated (4 ± 1°C) temperature may be due to multiplication of micro organisms (Bawa *et al*., 1988).

As per raw meat grading and marketing rules 1991 (India), 60% of the samples (three out of five samples in a batch) tested should have aerobic plate count not more than $\log_{10}$ 6.0 cfu/g, whereas 40% of the samples (two out of five samples in a batch) can show a count up to $\log_{10}$ 7.0 cfu/g (Joshi, 1994).

Russel *et al*., (1996) stated that a favourable pH for the growth of spoilage bacteria for meat was in the range of 5.5 – 7.0. Slime formation, structural components degradation,

off odours and appearance change were found in meat as a result of microbial growth within this pH range.

Stolle, (1998) stated that the total plate count indicated a fairly good standard of hygiene cattle slaughter.

Microbial counts (mean $\log_{10}$ cfu/g of all treatment samples of restructured emu steaks cooked to 60°C was lower ($P<0.05$) than counts on the uncooked samples. Considering the relatively low aerobic plate count of the raw restructured emu steaks for all binding systems tested, 90%, 92% and 99% destruction of aerobic bacteria by cooking steaks to 60, 66 and 75°C respectively, effectively provided a potentially safe, ready to eat, meat product (Shao *et al*., 1999).

Seydim *et al*., (2006) observed that the initial total viable count for the ground ostrich meat was slightly higher than that typical of ground beef but not different than that reported by Otremba *et al.,* (1999) for prefrozen ground and vacuum packaged ostrich meat.

Soriano *et al.* (2000) reported that aerobic plate count of cooked meat samples ranges from <1.00 to >6.04 log10 CFU/g.

A few available microbiological data for logical conditions of carcasses of and comminuted meat from emus would be comparable with the conditions of ostrich carcasses and meat (Shao *et al*., 1999; Gill *et al*., 2000).

Gill *et al*., (2000) reported that ostrich and emu carcasses had greater numbers of total aerobes than beef carcasses indicating more processing contamination for ostrich slaughter in small slaughter plants.

According to physico – chemical (pH, extract release volume, thiobarbituric acid values) and sensory (colour, flavor, juiciness, tenderness, overall acceptability) evaluation, patties and sausages made from emu meat are acceptable for up to 42 days of refrigerated (4°C) and 90 days of frozen (-18°C) storage (Sales, J. 2007).

Thomas *et al.,* (2007) found that aerobic mesophilic bacterial counts were higher for the buffalo meat nuggets made from emulsion with higher temperatures (34.8°C).

Bharti *et al.,* (2011) stated that the microbial count (cfu/g) in total plate count and lipolytic count were significantly lower (P<0.05) in chicken tikka and in all groups of chicken tikka, the microbial count increased significantly with advancement of storage period.

2.5.2 Salmonella

Bacteria species that include Pseudomonas, Micrococcus, Streptococcus, Sarcina, Lactobacillus, Salmonella, Escherichia, Clostrdius and Bacillus are found frequently on meat (Nychas and Jassou, 1997; Arnaut – Rollier *et al*., 1999; Lin *et al*., 2004).

Salmonella should be detected in not less than one out of 25g samples of meat. (ICMSF, 1974).

2.5.3 Coliforms

Growth of coliform bacteria would occur over a temperature range of 20 - 44°C (Buxton and Frazer, 1977).

2.6 VALUE ADDED PRODUCTS

Miller and Holben, (1997) suggested that future evaluation of emu using different product preparation may allow the consumers to access the meat in a situation more conductive to everyday life, preferably emu is a red meat, provides a lower fat alternative to beef and turkey.

Gujral *et al.,* (2002) stated that minced meat is used for the preparation of a variety of products such as patties, meat balls, kebabs etc., by incorporation of spices and condiments.

Reddy *et al.,* (2004) found that emu meat could be utilized upto 85 to 90% in preparation of patties and sausages without affecting the sensory qualities of the products. They also found that fried emu meat scored significantly (P<0.05) higher organoleptic values than steam cooked emu meat.

2.6.1 Emulsion stability

Correia and Mittal, (1991) reported that in meat emulsions the relevant functional properties included water holding capacity, emulsifying properties, emulsion stability, gelatin, colour, cohesion of particles etc. These functional properties were influenced by the quantity, composition, conformation and physical properties of constituents.

Emulsion stability is the ability of the emulsifier to stabilize an emulsion following it's formation and sometimes following certain stress condition (Hung and Zyas, 1991).

2.6.2 Product yield

Trout *et al.,* (1992) reported that there was decrease in product yield with increase in added fat level due to release of higher amount of liquid during cooking.

Tseng *et al*., (2000) measured the yield and gel strength of meat-balls and found that they increased ($P<0.05$) without any obvious effect and colour.

Restructuring emu steaks with combinations of different binders (fibrinogen / thrombin, algin / calcium lactate, phosphate / salt) resulted in higher pH values and cooked yields, but lower binding strength, compared to restructured beef steaks (Shao *et al*., 1999).

Meltem Serdaroglu and ozlem Degirmencioglu (2004) stated that per cent cooking yield was determined by calculating weight differences of samples before and after cooking.

Karthick, 2012 observed that the cooking yield of emu cutlet was found to be higher than beef and chicken cutlet. Similar results were found by Salahuddin *et al*; (1991) and Dushyanthan *et al.*, (2008).

2.7 Sensory evaluation

Consumer acceptance is a complex process in which perceived information from foods is integrated during tasting. While instrumental testing provides useful information, the complexity of the changes due to new raw meats, application in meat products in relation to acceptance could only be perceived by discrimation and consumer tasting (Kennedy, *et al*., 2004; Lawless and Heymann, 1999).

Szczesniak, (2002) used both sensory evaluation techniques and instrumental measurements in food texture research to assess texture parameters, correlations were generally used to assess the relationship between the instrumental measurement and sensory perception inorder to predict consumer responses or to evaluate quality control tools or parameters.

Resurreccion, (2003) concluded that consumer preferences for meat products, from a sensory stand point were influenced by appearance, tenderness, flavor and juiciness; reliable mathematical models may be developed that can be used to predict consumer acceptance scores from descriptive analysis ratings or physic-chemical measurements.

According to physico-chemical (pH,extract release volume, thiobarbituric acid values) and sensory (colour, flavour, juiciness, tenderness, overall acceptability) evaluation, patties and sausages made from emu meat are acceptable for up to 42 days of refrigerated (4ºc) and 90 days of frozen (-18ºc) storage. Frying resulted in more organoleptical acceptability of emu products than moist cooking (Prabhakara Reddy *et al*., 2004).

Consumer needs not only lean, but tasty meat, characterized by good culinary, technological and biological properties *(*Jukna *et al.,* 2005*)*.

Appearance

In the studies reported by Dingle *et al*., (1995) there were no or few significant differences in the objective evaluation of different emu muscles. In the studies reported by Mann *et al*., (1995), there were small, but significant differences in the subjective evaluation of muscle colour, the brightest red colour being the M. Iliotibialis cranialis and the darkest being the M. Iliofemoralis on a 1 to 8 scale of bright cherry red to very dark colour.

Flavour

In his findings D. R. Daniel, (1995) states that regardless of the type of cut used and temperature, panelists rated the meat flavor intensity as moderately intense (6.2). Out of 270 responses, 64.8% characterized the emu meat as having a slightly gamey off – flavor. He also reported that the meat flavor intensity did not increase or decrease substantially as the temperature changed. On an average, 95% of the responses characterized emu meat as having a slightly to extremely intense meat – flavor intensity. He suggested that to optimize tenderness and juiciness in emu and still retain desirable meat flavour, the medium degree of doneness (66ºc) was ideal.

Tenderness

Tenderness is the most important quality characteristic sought by the average meat consumer. Tenderness usually refers to the ease of shearing or cutting during mastication, while texture is related to the mealiness, greasiness, softness and structural fineness of the meat before and after mastication. The ultimate evaluation of tenderness is subjectively determined by the consumer (Lawrie, 1991).

Koohmaraie (1996) reported that the following variables have been proposed to influence meat tenderness; animal age and gender, rate of glycolysis, amount of solubility of collagen, sarcomere length, ionic strength and degradation of myofibrillar proteins and concluded that the rate and extent of post – mortem proteolysis best explain the variation in tenderness at a constant age.

Berge *et al*., (1997) observed that the tenderness of meat, cooked to 60ºc, differed between muscles and decreased with increasing age, thus reflecting the changes occurring in the concentration and in the heat stability of the intramuscular connective tissue. Also they obtained reduced meat tenderness values for older emus using a sensory panel, whereas instrumental measurements were not able to detect any difference.

Variation in collagen proteolysis and sarcomere length and the degree of their interaction with one another determine the tenderness of individual muscle (Wheeler *et al*., 1999)

Juiciness

Thompson *et al*., (1995) evaluated tenderness both objectively and subjectively in emu meat. Higher cooking temperatures were found to have adverse effect on tenderness and juiciness of emu meat. The sensory evaluation of cooked meat showed a marked heterogeneity of tenderness among the emu muscles.

Jerky made from emu meat was rated as tougher than that made from beef or turkey by both subjective and objective evaluation, but also rated the chewiest and most palatable (Carr *et al*., 1997).

In a study by Hoover *et al*., (1995), "Restaurant consumer acceptability of grilled emu steak", consumers ranked the importance of quality attributes and found tenderness ranked 3.5 (highest ranking was 5) followed by the juiciness 3.0.

Compared to beef, emu meat was rated via sensory evaluation as either more tender, juicier and more flavourful (Adams *et al*., 1997) or to be similar in overall flavor, juiciness and palatability (Offerman and Sim, 1996).

Overall palatability

Objective tests of emu and ostrich meat eating quality by J. G. Dingle, (1997) have shown that although there are differences between individual muscles, average quality is similar and would be classed as tender in comparison with beef.

Results from focussed research into meat eating quality revealed that tenderness, juiciness, flavor and overall palatability remain the most sought after attributes by consumers. Tenderness is deemed most important (Miller *et al*., 2001).

Reddy *et al*., (2004) observed that frying resulted in more organoleptical acceptability of emu products than moist cooking and patties and sausages made with emu meat were more organoleptically acceptable up to 42 days at refrigerated ($4 \pm 1^{o}C$) storage.

All the sensory attributes viz., appearance and colour, texture, juiciness and overall acceptability of chicken tikka were significantly increased with tumbling period (Bharti *et al*., 2011).

Karthick, (2012) observed that the emu cutlets were more acceptable than beef and chicken cutlets based on the odour score.

2.8 Histological studies

Dimov *et al*., (1994) in their histochemical studies of muscle fibre of buffalo calves fattened to different live weights noticed larger diameter in white fibres than the red and intermediate muscle types. They also inferred that all the three fibres increased in fibre diameter with increase in fattening time.

CHAPTER III

MATERIALS AND METHODS

A study on carcass characteristics and meat quality traits of emus of two different age groups (15 and 18 months) was undertaken at the Department of Meat Science and Technology, Madras Veterinary College, Chennai – 7, utilising sixteen emu.

3.1 SLAUGHTER AND DRESSING OF BIRDS

Emus of two different age groups 15 and 18 months (8 numbers in each group) were procured from "VC Emu Farms", Erumakuttapallam, Salem, and were transported in closed vehicle to the Department of Meat Science and Technology. The birds were given rest in the lairage and off fed overnight. The birds were individually weighed and subjected to thorough ante – mortem inspection and slaughtered as per the standard procedure adopted at the Department of Meat Science and Technology, Madras Veterinary College, Chennai – 600 007. (Plate 1)

After evisceration, a detailed post-mortem inspection of the carcasses and visceral organs were carried out and then the carcasses were fabricated.

The following components of the bird were separated, weighed and measured: Blood, feathers, subcutaneous fat, skin, shank, wings, eviscerated carcass, trachea, oesophagus, kidneys, gizzard, stomach, heart, liver, gall bladder, lungs, pancreas, spleen, small intestine, large intestine and caeca. The gizzard, stomach and intestines were also emptied and prior weights were recorded. Carcasses were washed and then chilled at 3 ± 1°C for 24 hours and then fabricated.

3.2 CARCASS CHARACTERISTICS

3.2.1 Live weight

The live weights of the birds were recorded prior to slaughter after ante mortem inspection.

3.2.2 Carcass weight

The weights of the carcasses were recorded immediately after slaughter.

3.2.3 Dressing percentage

The dressing percentage was calculated as:

Dressing % = (Carcass weight / live weight) x 100

3.2.4 Chiller shrinkage

Weights of the carcasses before chilling and after 24 hours of chilling at a temperature of 3 ± 1°C were recorded. The loss of weight after chilling the carcasses were recorded to calculate the percent chiller shrinkage.

3.2.5 Meat: Bone Ratio

The carcasses were taken out after 24 hours of chilling from the chiller (3 ± 1°C) and the lean meat, separable fat and bone were separated. The weights of the lean along with fat and bone were recorded to calculate the meat: bone ratio.

3.2.6 Weight and Yield of edible and inedible offals

After evisceration, followed by post-mortem inspection of the edible and inedible offals, their weights were recorded with weigh balance and their yields calculated with respect to live weights.

3.2.7 Carcass measurements

Measurement of carcass length, shank length, chest girth, length of the neck and intestines, Gigot length and Gigot width were recorded before fabrication.

- Carcass length was measured from the anterior of the last cervical vertebra to the anterior of the last coccygeal vertebra.
- Shank length was measured by measuring the length between the genu and the regiotarsalis.
- The chest girth was measured as the circumference of the carcass behind the wings, through the anterior border of the breast bone crest and the central thoracic vertebra.
- The length of the neck was measured from the first cervical vertebra to the last cervical vertebra.
- The length of the intestines was measured from the tip of the ileum to the end of the rectum.
- The Gigot length was measured from the bottom of the 'V' joint of flat in the crutch to the inner edge of the proximal sesamoid on the break – joint surface of the tibia by keeping the carcass on a flat table without any external pressure, stretching and pulling as per the method followed by Anous and Mourad (2001).
- Gigot width was measured by taking the maximum width netween the outer edges of the iliac wings of pelvis by keeping the carcass on a flat table without

any external pressure, stretching and pulling as per the method suggested by Anous and Mourad (2001).

3.2.8 Carcass Fabrication

Carcasses were weighed after chilling before fabrication. The carcasses were fabricated as per procedure outlined by the Department of Meat Science and Technology into Neck, Rib, Breast, Thigh, Drumstick, Loin and Rump. (Plate 2).

The carcasses were halved by making an incision in between the 5^{th} and 6^{th} intercostal space, after removing the neck at the last cervical vertebra. The thigh and the drumstick were separated by cutting approximately 4 to 5 inches below the joint connecting the femur, tibiotarsus and fibula. The portion left after separating drumstick and thigh was then separated into two portions by making an oblique cut posterior to the hip joint insertion.

The anterior portion was called the loin and the posterior portion the rump. The quarter including the ribcage formed the breast. The cuts were weighed individually and stored at -18 ± -1°C for subsequent analysis.

3.3 PHYSICO - CHEMICAL CHARACTERISTICS

Samples taken from the drumstick, breast and thigh regions of emus were subjected to analysis of physico-chemical characteristics and meat quality parameters.

The influence of age (15 and 18 months) on pH, water holding capacity, extract release volume, R – value, fibre diameter, Sarcomere length, Myofibrillar fragmentation index, thiobarbituric acid number, tyrosine value and of emu meat at different storage periods (0, 1^{st}, 2^{nd}, and 7^{th} day) were carried out.

The influence of age and muscle regions (drumstick, thigh and breast) on the pH, water holding capacity, myoglobin content, shear force value and collagen content of emu meat were carried out.

3.3.1 pH

The assessment of pH of the breast, thigh and drumstick muscle samples of emus (2-4 hours of slaughter) was made using a digital pH meter (Digisun electronic system, model: 2001). About 5g of emu meat was homogenised with 45 ml of distilled water in a laboratory blender for about one minute. The pH was recorded by immersing the combined glass electrode of digital pH meter in the homogenate. The pH meter was calibrated using pH 4.0, 7.0 and 10.0 as per the user manual instructions, prior to measurement. The pH of the meat samples were recorded on different periods (0, 1st, 2nd and 7th day) of storage and for different muscle regions.

3.3.2 Water holding capacity (WHC)

The estimation of water holding capacity of the breast, thigh and drumstick muscle samples of emus were carried out by adopting the filter paper press method recommended by Grau and Hamm (1953, 1957) with certain modifications. Approximately 300 mg of muscle tissue was kept in between a folded whatman No. 1 filter paper. Two glass slides were kept one below and one above the folded filter paper.

The muscle tissue was subjected to a downward force by keeping a 100g weight on the top of the glass slide for 3 minutes. The entire process was carried out on a hard top table. The area of the two resultant impressions left on each half of the filter paper on account of the force was measured using compensatory polar planimeter (Fuji, Japan) with 181.4 as a constant and 1: 1 scale and expressed in square centimetres. The water holding capacity of the meat samples were recorded at (0, 1st, 2nd and 7th day) of storage and for different muscles.

3.3.3 Extract release volume

Extract release volume was determined by the modified method of Pearson (1968). 15g of fresh meat samples were blended with 60 ml of extraction reagent for two minutes in a laboratory blender. Extraction reagent with a pH 5.8 is prepared by taking 50 ml of 0.2 M

potassium di – hydrogen orthophosphate and 3.72 ml of 0.2 M sodium hydroxide and the volume made up to 200 ml with distilled water.

The blended contents are quantitatively transferred to a glass funnel provided with filter paper (Whatman No.1, 18.5 cm diameter). The filter paper is folded thrice so as to make 8 sectors and filtrate collected in 100 ml measuring cylinder and the volume of filtrate collected in 15 minutes at a temperature of 20°C is reported as ml of extract release volume of the sample.

3.3.4 R - value

R – value is an indicator of ATP breakdown in post-mortem muscle. Samples were taken at 0, 1st, 2nd and 7th day post-mortem and stored below -70°C and analysed without thawing according to the procedure outlined by Honikel and Fischer (1977). 2 g of muscle sample was homogenised in 10 ml of 0.1 M perchloric acid. The homogenate was filtered in Whatman No.1 filter paper and from the filtrate 0.1 ml was taken out and diluted with 4.9 ml of 0.1M phosphate buffer with pH 7.0. The absorbance at 250nm (IMP) and 260 nm (for ATP) were measured with phosphate buffer as reference and the R- value calculated as the ratio of absorbance measurements at 250 and 260 nm.

3.3.5 Fibre diameter

Muscle fibre diameter was assessed according to the method outlined by Jeremiah and Martin (1982). Five gram sample of emu drumstick, thigh and breast muscles were cut into small pieces and homogenised separately in a mixer grinder at a low speed for two 15 second period, interspeed with a 5 second resting interval in a 30 ml solution containing 0.25M sucrose and 1mM ethylene diamine tetra acetic acid to form slurry. One or two drops of slurry was then transferred on to a clean microscopic slide and covered with a cover slip. The suspension was examined under low power in a light microscope fitted with 10x objective and 8x eyepiece equipped with calibrated micrometer.

Muscle fibre diameter was measured as the mean cross sectional distance in micrometer between the exterior surface of the sarcolemma of 20 randomly selected muscle fibres. Muscle fibre diameter was estimated at 0, 1st, 2nd and 7th day post – mortem.

3.3.6 Sarcomere length

Sarcomere length of the muscle fibre of emu was measured as per the method outlined by Cross *et al*., (1980) with certain modifications. A 5 gram sample of emu drumstick, thigh and breast muscles were cut into small pieces and homogenised at low speed in 30ml chilled 0.25M sucrose solution (0.25M). A drop of the homogenate was then transferred onto a slide. The slide was examined under a phase contrast microscope (100x objective and 8x eyepiece) with oil immersion.

If the fibres were not sufficiently broken apart, the sample was homogenised for an additional period of 20 - 30 seconds, taking care to ensure that the myofibrils were not homogenised to less than 10 sarcomeres. The length of the sarcomeres measured by starting from one edge of the slide and moving straight across using a calibrated micrometer.

3.3.7 Myofibrillar fragmentation index (MFI)

Myofibrillar fragmentation index (MFI) was determined as per the method outlined by Davis *et al.*, (1980). Samples of emu drumstick, thigh and breast muscles were frozen. The frozen slices were cut and approximately 10 gm of cubes were then transferred to a virtis glass flouted homogenisation flask containing 50ml of cold solution of 0.25M sucrose and 0.02M potassium chloride. The muscle cubes were allowed to thaw for 5 minutes. With two virtis stainless steel blades aligned and positioned 1 mm below the surface of the solution and set in reverse position, the sample was homogenised in a “Virtis homogeniser 45” (Virtis Company, Gardinar, New York, USA) for 40 seconds at full speed.

The homogenate was filtered through 250 µm stainless steel cloth screen in the filtration unit. The homogenate was stirred to enhance the filtration process. The resulting

fraction (muscle fragments greater than 250 µm in size) with screen was blotted on whatman No.1 filter paper and allowed to dry at 25°C. After 40 minutes of drying period, the net fraction weight in g/cm^2 was determined and the myofibrillar fragmentation was calculated as follows:

Myofibrillar fragmentation index (MFI) = Net fraction weight (g/cm^2) X 100.

3.3.8 Shear force value

The shear force values of emu drumstick, thigh and breast muscle samples of two different age groups (15 and 18 months) were assessed at three different points using Warner - Bratzler meat shear (G. R. Electric manufacturing company, Model No.04347, Manhattan, U.S.A).

The samples of meat about 100 g in each muscle portions were cooked at 15lbs pressure for 15 minutes in a domestic cooker. The cooked samples were cooled in a refrigerator and a core having 1.25 cm diameter and about 3cm length was taken from the cooked and cooled samples. Three readings were taken from each core. The average of the five readings were recorded as the mean shear force required to shear through the core and expressed in kg/cm^2.

3.3.9 Collagen content

Collagen content was determined using hydroxyproline assay. The amino acid hydroxyproline was determined as described by Wossner J. F., (1961).The presence of the amino acid hydroxyproline in collagen (about 13%) is a unique feature because this amino acid occurs in only a few proteins, such as elastin (about 1%). Therefore, hydroxyproline has been used for many years as a means of determining amount of collagen present in a tissue. Hydroxyproline content was converted to total collagen using a factor of 7.57 (Baker *et al*., 1954).

Sample Preparation

The sample was taken and cut into small pieces. Hydrolysis tube containing 5ml of 6N Hydrochloric acid was taken and a piece of sample was added to each tube. The tubes were maintained at 110°C for 18 hours in a water bath and then removed. The solutions were poured on to separate china dishes and placed in a water bath. [This facilitates the evaporation of traces of Hydrochloric acid.] 1ml of distilled water was added to the hydrolysis tube and poured again in to china dish. The above step was carried out for 10 times to bring the pH to neutral. The final solution was stored for further assay process.

Stock preparation of Standard

One mg of standard Hydroxyproline was dissolved in 1ml of 0.01N Hydrochloric acid. From this solution, 1ml was taken and diluted to 100ml with 0.01N Hydrochloric acid. This stock consists of 0.01mg of Hydroxyproline per ml of solution.

Assay

Five test tubes excluding one for the control were taken and 0.2, 0.4, 0.6, 0.8, 1.0ml of stock were added to the respective tubes. In each test-tube, the solution was made upto 2ml by adding the corresponding volume of 0.01N HCl. The control test-tube consists of 2ml of 0.01N HCl. 1ml of Chloramine T was added to all the six test-tubes. The tubes were shaken well and allowed to stand for 20minutes at room temperature. The tubes were shaken well after adding 1ml of Perchloric acid to all the test - tubes and allowed to stand for 5minutes. The resulting product was mixed with 1ml of PDAB and maintained at 60 degree Celsius for 20 minutes and cooled for 5minutes. Spectrophotometric readings of the samples were taken at 557nm. The hydroxyproline in the samples were quantified and multiplied with conversion factor to represent the collagen content of the emu meat samples.

3.3.10 Texture profile analysis

Texture profile analysis was conducted using a Stable Microsystems Texturometer (Stable Microsystems Ltd., England, UK) model TA-HD plus texture analyser attached to

software, texture expert. The texture profile was analysed as per the method followed by Bourne (1978). Triplicate samples in each trial were compressed twice to form a “two bite” work force compression curve. A cylindrical probe of 75 mm diameter was used.

The load cell capacity was 500 kg with a load range of 0 – 500 kg at cross head and the char speed was 50 mm / min, pre – test speed – 1, post – test speed – 5, time – 5 seconds, trigger type - Auto , trigger force – 5 gram. The distance between the probe and the base is calculated according to the height of the sample such that the probe compresses half of the sample (i.e,) 1.5 times of the sample height. The parameters determined were as presented below.

a) Hardness 1 (kgf) = maximum force required to compress the sample first time

b) Hardness 2 (kgf) = maximum force required to compress the sample second time.

c) Springiness (mm) = ability of sample to recover to its original shape after the deforming force was removed. It is the extent of elastic recovery property of the meat product.

d) Cohesiveness (ratio) = extent to which the sample could be deformed prior to rupture (A_2/A_1, A_1 being the maximum force required for the first compression and A_2 being the maximum force required for the second compression.

e) Gumminess (N) = force required to disintegrate a semisolid meat sample for swallowing (hardness x cohesiveness).

f) Chewiness (kgf.mm) = work to disintegrate a semisolid meat sample for swallowing (springiness x gumminess).

3.3.11 Thiobarbituric acid (TBA) number

Thiobarbituric acid (TBA) reagent

Thiobarbituric acid (TBA) reagent was prepared according to Pearson (1973) by dissolving 0.2883g of thiobarbituric acid reagent in sufficient quantity of 90% glacial acetic acid and by slight warming, the volume being made up to 100ml with 90% glacial acetic acid.

Trichloro acetic acid (TCA) extract

Twenty grams (20g) of sample was blended in the laboratory blender (Remi, India) with 50ml of cold 20 % trichloroacetic acid (TCA) for 2 minutes. The blended contents were rinsed with 50 ml of distilled water, mixed together and filtered through the filter paper (Whatman No.1, 18.5 cm diameter) and the filtrate was collected in a 100ml capacity measuring cylinder. The filtrate, termed the trichloro acetic acid (TCA) extract was used in the estimation of thiobarbituric acid number (TBA No.) and tyrosine value (TV).

Thiobarbituric acid (TBA) number was measured by a modified method by Strange *et al*., (1977), with a little modification in the technique. 5ml of the TCA extract was mixed with 5ml of TBA reagent in a test tube. The test tube was kept in a water bath at 100°C for 30 minutes along with a test tube containing a blank of 5ml of 10 % trichloro acetic acid (TCA) and 5ml of TBA reagent.

After cooling the tubes in running water for about 10 minute, the developed colour was measured as absorbance at 530nm in the spectrophotometer (SL – 164, double beam UV – VIS spectrophotometer, ELICO India Ltd, Hyderabad) at medium sensitivity and reported as TBA number in mg malonaldehyde / kg of sample.

3.3.12 Tyrosine value

Tyrosine value was determined by the modified method of Strange *et al*., (1977). 2.5 ml of TCA extract was diluted with equal quantity of distilled water in a test tube. To this 10 ml of 0.5 N NaOH was added followed by 3 ml of diluted Folin coicalteau's phenol reagent (1 part folin ciocalteau's phenol reagent with 2 parts distilled water). After mixing and keeping for 15 minutes at room temperature the developed colour was measured as absorbance at 660 nm in a spectrophotometer (SL – 164, double beam UV – VIS spectrophotometer, ELICO India Ltd., Hyderabad) at low sensitivity, using a blank containing 5 ml of 5% trichloroacetic acid (TCA) with 10 ml of 0.5 N sodium hydroxide (NaOH) and 3

ml of diluted Folin ciocalteau's phenol reagent. By reference to the standard graph, the tyrosine value was calculated as mg of tyrosine / 100g of sample.

Standard graph for estimation of tyrosine value

Hundred milligrams (100 mg) of tyrosine was dissolved in 500 ml of 5% trichloroacetic acid (TCA) in a volumetric flask. The following volumes of the above tyrosine solution were then transferred to a series of 100 ml volumetric flasks: 0, 1, 3, 5, 7, 10, 15, 20, 25, 30, 35, 40, 45 and 50 ml. They were made up to the mark with distilled water and mixed thoroughly. Five ml of each of the tyrosine solution was shaken with 10ml of 0.5 N (NaOH) and 3 ml of diluted Folin ciocalteau's phenol reagent and then treated as described for tyrosine value. The standard graph was prepared with known concentration of tyrosine in the solutions and their corresponding absorbance values following the least square method.

3.3.13 Myoglobin content

The percent of myoglobin of emu meat samples was estimated by the method described by Krzywicki (1982) with slight modifications. Two gram of meat was scraped from the surface of the sample. Myoglobin was extracted with 25ml ice cold 0.04M phosphate buffer, pH 6.8. The meat and buffer mixture was homogenised for 30 sec, using homogenizer (Silverson, England) allowed to stand for 1hour at 4°C, then centrifuged at 6500 rpm for 10 min at 4°C and then filtered through Whatman No. 541 filter paper. The relative concentration of oxymyoglobin (percentage of the total myoglobin) was calculated using absorbance measurements at 525, 545, 565 and 572 nm using the following formula:

$$\mathbf{Ox = 0.882\ R1 - 1.267\ R2 + 0.809\ R3 - 0.361}$$

where, Ox = oxymyoglobin, R1, R2 and R3 are absorbance ratios A572/A525, A565/A525, A545/A525 respectively. The absorbance spectra of supernates were obtained on a microplate spectrophotometer (Micro Quaint, USA).

3.3.14 Spectrophotometric assay of meat colour

Colour of breast, thigh and drumstick muscles of emu meat was tested using Hunter Lab Mini scan XE plus separate colorimeter (Model No. 45/0-L, Reston Virginia, USA) with geometry of diffuse/80 (sphere- 8mm view) and an illuminant of D65/10deg . Colorimetry measures colour with quantitative physical methods and defines them within well established numerical values. Here they are expressed using the standard Hunter L*, a*, b* system.

L*, a*, b* values (non-dimensional units) refer to the three axes of the system: a lightness axis (white-black, L8); and two axes representing both hue and chroma, one red green (a*) and the other blue-yellow (b*). This system provides an advantage that colour differences between samples can be determined using simple computer programs.

The instrument was calibrated with black and white tile (L*=94, a*=1.10 and b*= 0.6) every time before the colour was expressed as L* (brightness), a* (redness) and b* (yellowness). The hue (relative position of colour between redness and yellowness) and chroma (colour intensity) was calculated as follows:

$$\textbf{Hue} = \tan^{-1}(b^*/a^*)$$

$$\textbf{Chroma} = \sqrt{(a^*)^2 + (b^*)^2}$$

Average value for each color parameter was determined by taking observation from five different places from each bird.

3.3.15 Drip loss

Drip loss was estimated as per the method outlined by Somers *et al*., (1985). A

2 cm thick chilled (3°C) emu muscle chop from the loin region was cut at the level of the posterior hip joint at about 24 h post slaughter. The weighed muscle chop was suspended in

plastic netting with a sealed preweighed plastic bag for 24 hours at 4°C. The weight of drip in the bag was then recorded and percentage of drip loss of the loin muscle was calculated.

Drip loss (%) = (Weight of drip /Weight of muscle) X 100

3.3.16 Cooking loss

A 2.5 cm thick loin chop was used for assessing cooking loss. The initial weight of chops thawed and blotted were recorded and the chop was cooked in a pressure cooker for 20 minutes under 15 lbs pressure. After completion of cooking, the chop was allowed to cool and blotted to remove the excess moisture and weight of the cooked and blotted chop was recorded (Neel *et al*., 1987). The cooking loss was calculated as follows:

Cooking loss (%) = [(Chop thawed blotted weight) – (Chop cooked blotted weight)]

---------- **X** 100

(Chop thawed blotted weight)

3.4 NUTRITIONAL QUALITY

3.4.1 Proximate composition

The proximate composition such as protein, fat, moisture and ash percents of emu meat samples were analysed by following the standard procedure of AOAC (1995). Moisture contents of emu muscle samples were determined by conventional air drying method recommended by AOAC using a hot air mechanical conventional oven. For fat estimation, SOCS plus (Model SCS 4, Pelican equipment Pvt. Ltd., Chennai) and for protein estimation, KEL plus (Model Classic DX, Pelican equipment Pvt. Ltd., Chennai) were used. Total ash content of emu muscles were determined by organic matter incineration at 600°C, as per AOAC (1995). The proximate compositions of the samples were expressed in percentage.

3.4.2 Mineral content

Wet ashing of samples

For the digestion of sample, about 10mg of meat was digested (wet ashing method) with 10ml each of HNO_3 (65%) and H_2O_2 (30%) in acid prewashed Teflon vessels. After standing overnight, samples were digested using microwave lab stations with the following program: 250 W, 1 min; 0 W, 1 min; 250 W, 6 min; 400 W, 5 min. After sufficient cooling, samples were moved to Teflon vessels and diluted to 25 ml with distilled – deionized water. Analytical blanks were prepared with each batch of digestion set.

Detection

Inductively coupled plasma-optical emission spectrometry (ICP-OES) (PERKINS ELMER OPTIMA 5300 DV MODEL) instrument was used for estimating the minerals. The sample was prepared in a solution form so that it could be easily aspirated through the nebulizer and the concentration of the elements to be determined was provided between 0.1 to 0.5 absorbance units. About 2ml of solution was utilized for each measurement. The working standards were analyzed at the beginning and end of a run and periodically during longer runs. According to the absorbance measurements, the concentration was measured directly, when the sample was well within the linear working range. The working condition of the instrument is presented below:

Wavelength limits for ICP - OES method:

Sl. No.	Elements name with symbol	Wavelength (nm)
1.	Aluminum (Al)	396.153
2.	Boron (B)	249.677
3.	Calcium (Ca)	317.933
4.	Cobalt (Co)	228.616
5.	Chromium (Cr)	267.716

6.	Copper (Cu)	327.393
7.	Ferrous (Fe)	238.204
8.	Magnesium (Mg)	285.213
9.	Manganese (Mn)	257.610
10.	Sodium (Na)	589.592
11.	Zinc (Zn)	206.200

3.4.3 Cholesterol content

Cholesterol content of emu meat was determined using cholesterol test kit (Span Diagnostics ltd., India) except that instead of blood serum, lipid extract was used as per the method followed by Rajkumar *et al*., (2004). Lipid extract was prepared by taking one gram of the sample and adding 10 ml of freshly prepared 2:1 chloroform : methanol solution and homogenised with laboratory model blender.

Homogenate was filtered using Whatman no.42 filter paper and to 5ml of the filtrate equal quantity of distilled water was added, mixed and centrifuged at 3000 rpm for 7 minutes. Top layer (methanol) was removed by suction. Volume of the bottom (chloroform) layer having cholesterol was recorded. This layer was then treated with 1% NaOH and filtered. From this 25µl of the sample was pipetted out into a test tube and kept in water bath (100°C) for 2-3 minutes till it got dried. To this 5ml of cholesterol reagent was added, mixed and kept in a boiling water bath for 90 seconds for colour development. The O.D. of standard and test against blank were taken at 530nm.

Total cholesterol (mg %) = [O.D. of sample/O.D. of standard] X

[Volume of chloroform layer (ml) / Weight of the sample taken (g)] X 200.

where, 200 is the concentration of standard.

3.4.4 Fatty acid composition

Fatty acid profile of emu meat samples were estimated and expressed in percentage. Fatty acid profile of these samples were estimated by the procedure followed in Palmquist and Jenkins (2003) with slight modification.

Gas Liquid Chromatography (GLC) analysis of fatty acids

Reagents

Ten percent (10%) methanol HCl was prepared. Added 20 ml of acetyl chloride drop by drop to 100 ml of methanol while stirring on a magnetic stirring plate.Fatty acid internal standard: non - adecanoic acid (19:0), 2.0 mg / ml in benzene, toluene, or heptane and stored in Teflon- lined screw cap tubes at 4°C.

Procedure

The procedure as described by Palmiquist and Jenkins (2003) was followed.

Samples were dried at 55°C before use. (100 mg of water was acceptable in the reaction mixture).Weighed duplicate 0.5g samples (or amount as appropriate to contain 10 to 50mg of Fatty acid) were taken into 20 x150 mm test tubes with Teflon - lined screw caps. The sealed tops were checked for leakage. 2 ml of internal standard (4.0mg) was added with a volumetric pipette. 3 ml of 10% methanol was added, tightly closed and mixed in the vortex. Kept at 90°C in a water bath for 2 hours and cooled to room temperature.

One ml of hexane or heptane was added. 10 ml of 6% Potassium bicarbonate (K_2Co_3) was added carefully to avoid sample loss. Then the tubes were vortexed and centrifuged for 5min at approximately 500 rpm to separate solvent layers. The supernatant layer was transferred to a 13 x 100 mm culture tube with Teflon- lined screw cap. Approximately 1g of sodium sulphate was added to the organic solvent. The tubes were again

vortexed and centrifuged. Now, the solvent layer was transferred to a 2ml GLC auto sampler vial and cap. The samples were stored at -20°C until GLC analysis.

Analysis

The retention time and quantitative correction factors to be applied for the range of fatty acids to be analysed were determined. The recovery of a fatty acid standard (eg.16.0 or 18.0) were determined by weighing 20 to 50 mg of pure standard; adding internal standard and run as for unknowns. Recoveries for duplicate analysis should be 100 ± 5% for both samples. Total fatty acid in the sample was equal to sum of areas for all fatty acid peaks compared to area for 4mg standard and reported as percentage of total fatty acid in a sample.

3.4.5 Amino acid composition

Amino acid composition of emu meat was estimated and expressed as mg/g of meat. The essential amino acid content was determined in a high performance liquid chromatography (HPLC). (Plate 3)

High performance liquid chromatography (HPLC)

Principle

Primary amines react readily with orthophtalaldehyde (OPA) in the presence of mercapto ethanol to form 1 thio substituted 2 alkyl isoindoles. These isoindoles have been shown to be well suited for HPLC separation. OPA derivatization procedures involve a rapid reaction and high sensitivity.

Reagents

Mobile phase A

a) Twenty millimolar (20mM) sodium acetate + 0.018% trimethylamine.

b) Adjust the pH to 7.20 ± 0.05 with 2% acetic acid.

Mobile phase B

a) Twenty percent (20%) of 100mM sodium acetate + 40% methanol + 40% acetonitrile.

b) Adjust the pH to 7.20 ± 0.05 with 2% acetic acid.

c) Orthopthalaldehyde reagent: commercially available HP

d) Stock standard : (Hewlett Packard)

Standard for amino acid mixture of different concentrations was provided by Hewlett Packard. The standards of concentrations were provided in the kit.

Instrument

Agilent 1100 HP – HPLC, USA with chemstation software was used.

Procedure

The procedure as described by Bruckner *et al*., (1991) was followed. As per the procedure, the instrument was calibrated using 1000 ppm, 500ppm, 250ppm standards individually. Mix 10µl of the standard in 60 µl borate buffer and 10 µl of OPA reagent in dilution vial and cyclomix. From this mixture 50 µl was injected in the HPLC using Hamilton syringes. Each standard should be individually run in the gradient program mentioned below.

The chromatogram for them was obtained. The two consecutive runs that have the same retention time been taken and the average of them were used for plotting the graphs in the calibration table. The procedure was termed as calibration and the curve obtained for the same was calibration curve. Take 10 µl of the sample in 60 µl borate buffer and 10 µl of OPA reagent in a dilution vial and cyclomix. From this mixture 50 µl was injected to the HPLC using Hamilton syringes.

After the sample was run, chromatogram was obtained for the same. From the chromatogram the area of the peaks were recorded and calibrated along with the standards and used for calculation.

HPLC parameters

a)	Reaction temperature (°C)	:	40
b)	Flow rate (ml/minute)	:	0.5
c)	Detection wavelength (nm)	:	VWD 338
d)	Injection volume (µl)	:	50

3.5 ORGANOLEPTIC QUALITY

Emu meat samples were cooked at 15 lbs pressure for 15 minutes. The cooked samples were served to the trained panellists drawn from the staff and PG students of Department of Meat Science and Technology, Madras Veterinary College, Chennai – 600 007. The members were provided with a score card having a nine point descending scale to assess the appearance, flavour, juiciness and tenderness. The overall palatability was assessed by calculating the average of the above attributes.

3.6 MICROBIOLOGICAL QUALITY

Total viable count, Salmonella and Coliform counts of the emu meat samples were determined by the method described by APHA (1984). Dehydrated media from Himedia, Mumbai were employed for the microbial assessment.

Preparation of samples

Five grams of meat sample were taken aseptically and homogenised with 45 ml of 0.1 percent sterile peptone water, using a sterile pestle and mortar to detain an initial dilution of $10^{-1.}$ Serial tenfold dilutions were made up to 10^{-6} in pre - sterilized tubes containing 9ml of 0.1 percent peptone water. The sample preparation and plating were carried out under laminar flow.

3.6.1 Total viable count

Seventeen and half grams of plate count agar was suspended in one litre of distilled water. The suspension was boiled and autoclaved at 15 lb pressure per square inch for 15 minutes to sterilize the media. One millimetre of inoculum (in duplicate) of each dilution was placed aseptically in identified petridishes. Molten and cooled plate count agar of 12 to 15 ml was poured to each petridish containing inoculum and mixed thoroughly. After solidification of the medium the petridishes were incubated 37°C for 48 hours in an inverted position. Following incubation the petridishes containing 25 - 300 colonies were counted and the number of colonies in the original suspension expressed as log value / g of meat by multiplying the counted colonies with the reciprocal of the dilution.

3.6.2 Salmonella

Fifty eight gram of brilliant green agar was dissolved in one litre of distilled water. The suspension was boiled and autoclaved at 15 lb pressure per inch for 15 minutes to sterilize the media. One millilitre of inoculum (in duplicate) of each dilution was poured aseptically in identified petridishes. Molten and cooled medium of 12 to 15ml was poured to each petridish containing inoculums and mixed thoroughly. After solidification of the medium the petridishes were incubated at 37°C for 48 hours in an inverted position.

3.6.3 Coliform count

Forty one and a half grams of violet red bile agar (VRBA) was dissolved in one litre of distilled water and boiled to dissolve the medium completely. One millilitre of inoculum (in duplicate) of each dilution was poured aseptically in identified petridishes. The sterile molten and cooled medium of 12 to 15ml was poured to each petridish containing inoculum and mixed thoroughly. After solidification of the medium the petridishes were incubated at

35°C for 18 - 24 hours in an inverted position. Dark red colonies, surrounded by a reddish zone were counted and expressed as log value/g of sample.

3.7 VALUE ADDED PRODUCTS

Meat products like sausages and nuggets were prepared from emu meat and quality characteristics of the products were compared with beef and chicken nuggets. The frozen meat (Emu, Beef and Chicken) was minced in 4mm Meat mincer (Omas, Model No. 169789, Electrolux Food Service, Italy). Emulsion was prepared by chopping the minced meat in bowl chopper (Mado MTK 662, Maschinen Fabric., Germany) and adding the following ingredients in a sequential order- Two percentage of salt, 10% of refined vegetable oil, 0.3% sodium tripoly phosphate, 0.012% sodium nitrite, 10% slushed ice. After chopping for 2-3 minutes, 2 % spice mix and 10% of refined wheat flour was added and chopping was done until emulsion was obtained.

The emulsion was stuffed in 10-20 mm diameter sheep casing using sausage stuffer (Mado MWF 591, Maschinen Fabric., Germany), and then the stuffed sausages were interlinked and cooked in water bath at 65°C. Nuggets were prepared by tightly packing the emulsion in stainless steel moulds of dimension 15x10x4 cm and cooking in steam for 30 minutes until the internal temperature reached 72°C. The moulds were cooled under running tap water to reduce the temperature to room temperature. Nuggets were then cut into uniform sizes of 1” cubes. The prepared products were subjected to taste panel studies and further analysis.

3.7.1 Emulsion stability

Emulsion stability was estimated as per the method outlined by Baliga and Madaiah (1971). Fifteen grams of emulsion was weighed and packed in polythene bags and heated at 80°C for 20 minutes in a constant temperature water bath. Then, the fluid released was drained and the sample was weighed.

The emulsion stability was calculated by using the formula,

$$\textbf{Emulsion stability (\%)} = \frac{\text{(Weight of cooked emulsion)}}{\text{(Weight of raw emulsion)}} \times 100$$

3.7.2 Product yield

The weights of the products were recorded immediately after filling the casing and after cooking from which the product yield was calculated by using the formula.

$$\textbf{Product Yield (\%)} = \frac{\text{(Weight of cooked product)}}{\text{(Weight of raw product)}} \times 100$$

3.8 SENSORY EVALUATION

The organoleptic qualities of emu meat products like sausages and nuggets were assessed by subjecting the products to a sensory scores of appearance, flavour, juiciness, tenderness and overall acceptability by a trained and semi – trained panel drawn from the Department of Meat Science and Technology, Madras Veterinary College, Chennai- 600 007 on a nine point hedonic scale as given in the score card (Annexure 1).

The members were provided with a score card having a nine point descending scale to assess the flavor, tenderness and juiciness of the products. The overall acceptability of the products was assessed by calculating the average of the above three attributes.

3.9 HISTOLOGICAL STUDIES

Histological studies of the emu meat were carried out. The tissues were collected in 10 per cent formalin and tissue sections were cut into 4 to 6 µ thickness. The cut sections were stained with Haematoxylin and Eosin (H&E) stain as per the procedure described by Bancroft and Gamble, (2008) (Plate 4)

3.10 STATISTICAL ANALYSIS

The data obtained in this study were analysed statistically in SPS software (version 20.0) as per the methods outlined by Snedecor and Cochran (1994). The significance between the two age groups (15 and 18 months) irrespective of storage periods was analysed by the test of significance ('t' test) and the significance between storage periods was analysed by one way anova individually for two age groups.

CHAPTER IV

RESULTS

Studies were conducted to ascertain the various carcass characteristics, physico – chemical, organoleptic qualities, amino acid and fatty acid profile, mineral content, value added product quality and histological parameters of meat from emus of two different age groups (15 and 18 months).

A total of sixteen emus subjected to this study were divided into 15 months and 18 months age groups. Each group consisted of 8 birds. The results of the study on the carcass characteristics and meat quality traits of emus of two different age

groups are presented in tables 1 to 21 with mean values and standard error along with test of significance and analysis of variance. The variations in carcass characteristics and quality parameters between age groups and muscle regions were compared by one way ANOVA and test of significance.

4.1. Carcass characteristics

4.1.1 Carcass characteristics

Mean values and standard error for live weight (kg), carcass weight (kg), chilled carcass weight (kg), chiller shrinkage (%), dressing per cent, meat: bone ratio, drip loss (%) and cooking loss (%) of emus of 15 and 18 months age groups are presented in Table 1 along with test of significance.

The mean ± S.E. values of live weight, carcass weight , chilled carcass weight, chiller shrinkage , dressing per cent , meat: bone ratio, drip loss and cooking loss of emus of 15 and 18 months age group were, 27.85 ± 0.29 and 30.62 ± 0.12, 18.12 ± 0.22 and 20.81 ± 0.17, 16.65 ± 0.27 and 19.59 ± 0.17, 8.14 ± 0.73 and 5.86 ± 0.28, 65.06 ± 0.41 and , 67.95 ± 0.34, 3.02 ± 0.04 and 2.65 ± 0.03, 1.71 ± 0.98 and 2.32 ± 0.76, 30.74 ± 0.15 and 31.19 ± 0.12 respectively.

Table 1: Influence of age on the carcass characteristics (Mean ± S.E.) of emu

Carcass characteristics	Age (months)		t - value
	15	18	
Live weight (Kg)	27.85 ± 0.29	30.62 ± 0.12	8.86**
Carcass weight (Kg)	18.12 ± 0.22	20.81± 0.17	9.44**

Chilled Carcass weight (kg)	16.65 ± 0.27	19.59 ± 0.17	9.07^{**}
Chiller Shrinkage (%)	8.14 ± 0.73	5.86 ± 0.28	2.91^{*}
Dressing per cent (%)	65.06 ± 0.41	67.95 ± 0.34	5.40^{**}
Meat : Bone ratio	3.02 ± 0.04	2.65 ± 0.03	5.52^{**}
Drip loss (%)	1.71 ± 0.989	2.32 ± 0.76	0.36^{NS}
Cooking loss (%)	31.19 ± 0.12	30.74 ± 0.15	3.15^{**}

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant (P<0.05), * * = highly significant (P<0.01).

The test of significance revealed highly significant (P<0.01) difference in live weight, carcass weight, chilled carcass weight, chiller shrinkage, dressing percentage, meat: bone ratio and cooking loss, and non – significant difference (P>0.05) in drip loss between 15 and 18 months emus.

4.1.2 Carcass measurements

Mean values and standard error for the carcass measurements (in cm) of the length of the carcass, neck, shank, trachea, oesophagus, intestine, chest girth, gigot length and gigot width of the emus of 15 and 18 month age groups are presented in Table 2 along with test of significance.

The mean ± S.E. values of the length of the carcass, neck, shank, trachea, oesophagus, intestine, chest girth, gigot length and gigot width of the emus of 15 and 18 months age groups were 46.43 ± 0.34 and 52.17 ± 0.32, 56.97 ± 0.24 and 62.35 ± 0.81, 53.26 ± 0.28 and 56.57 ± 0.30, 67.95 ± 0.33 and 75.78 ± 0.39, 71.33 ± 0.43 and 80.34 ± 0.38, 437.45 ± 1.91 and 452.12 ± 1.19, 67.34 ± 0.19 and 72.06 ± 0.37, 43.08 ± 0.52 and 53.20 ± 0.33, 27.87 ± 0.19 and 33.86 ± 0.18 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the length of the carcass, neck, shank, trachea, oesophagus, intestine, chest girth, gigot length and gigot width between emus of 15 and 18 months age groups.

4.1.3 Weights and yields of edible offals

Mean values and standard error for the weights (kg) and per cent yields of edible offals like heart, liver, kidney and gizzard from emus of 15 and 18 month age groups are presented in Table 3 along with test of significance.

The mean ± S.E. values for the weights of edible offals like heart, liver, kidney and gizzard of 15 and 18 months age group were 0.38 ± 0.02 and 0.42 ± 0.01, 0.40 ± 0.02 and 0.44 ± 0.00, 0.18 ± 0.02 and 0.23 ± 0.01, 0.33 ± 0.02 and 0.37 ± 0.01 respectively.

Table 2: Influence of age on the carcass measurements (Mean ± S.E.) of emu

Carcass measurements (cm)	Age (months)		t - value
	15	18	
Carcass length	46.43 ± 0.34	52.17 ± 0.32	12.32**
Neck	56.97 ± 0.24	62.35 ± 0.81	6.35**
Shank	53.26 ± 0.28	56.57 ± 0.30	8.15**
Trachea	67.95 ± 0.33	75.78 ± 0.39	15.32**
Oesophagus	71.33 ± 0.43	80.34 ± 0.38	15.66**
Intestine	437.45 ± 1.91	452.12 ± 1.19	6.53**
Chest girth	67.34 ± 0.19	72.06 ± 0.37	11.23**
Gigot length	43.08 ± 0.52	53.20 ± 0.33	16.60**
Gigot width	27.87 ± 0.19	33.86 ± 0.18	22.55**

No. of samples – 8, means bearing different superscripts differ significantly.

* * = highly significant (P<0.01).

Table 3: Influence of age on the weights and per cent yields of edible offals (Mean ± S.E.) of emu

Edible offals (Kg)	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Heart	0.38 ± 0.02	0.42 ± 0.01	6.75^{**}	1.35 ± 0.02	1.39 ± 0.02	1.74^{NS}
Liver	0.40 ± 0.02	0.44 ± 0.00	5.95^{**}	1.43 ± 0.02	1.45 ± 0.02	0.82^{NS}
Kidney	0.18 ± 0.02	0.23 ± 0.01	6.13^{**}	0.65 ± 0.02	0.74 ± 0.01	3.53^{**}
Gizzard	0.33 ± 0.02	0.37 ± 0.01	2.97^{*}	1.18 ± 0.02	1.22 ± 0.03	1.14^{NS}

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant (P<0.05), * * = highly significant (P<0.01),

NS = Non – significant (P>0.05).

The test of significance revealed a highly significant difference (P<0.01) in the weights of heart, liver and kidney and significant difference (P<0.05) in the weights of gizzard between emus of 15 and 18 months age groups.

The mean ± S.E. values for the percent yield of edible offals like heart, liver, kidney and gizzard of 15 and 18 months age group were 1.35 ± 0.02 and1.39 ± 0.02, 1.43 ± 0.02 and 1.45 ± 0.02, 0.65 ± 0.02 and 0.74 ± 0.01, 1.18 ± 0.02 and 1.22 ± 0.03 respectively. The test of significance revealed a highly significant difference (P<0.01) in the per cent yields of kidney and non - significant difference (P>0.05) in the percent yields of heart, liver and gizzard between emus of 15 and 18 months age groups.

4.1.4 Weights and yields of inedible offals

Mean values and standard error for the weights (kg) and per cent yields of inedible offals like blood, feather, skin, shank, head, lungs, intestines, proventriculus, spleen, trachea, oesophagus and wings from emus of 15 and 18 month age groups are presented in Table 4 along with test of significance.

The mean ± S.E. values for the weights of inedible offals like blood, feather, skin, shank, head, lungs, intestines, proventriculus, spleen, trachea, oesophagus and wings of 15 and 18 months age groups were 1.20 ± 0.02 and 1.63 ± 0.01, 0.41 ± 0.02 and 0.55 ± 0.01, 2.81 ± 0.01 and 3.19 ± 0.01, 1.06 ± 0.02 and 1.38 ± 0.01, 0.31 ± 0.01 and 0.36 ± 0.01, 0.30 ± 0.02 and 0.35 ± 0.01, and 0.59 ± 0.02 and 0.70 ± 0.02, 0.15 ± 0.01 and 0.07 ± 0.00, 0.03 ± 0.00 and 0.07 ± 0.00, 0.14 ± 0.02 and 0.16 ± 0.01, 0.14 ± 0.02 and 0.12 ± 0.01 and 0.05 ± 0.00 and 0.07 ± 0.00 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the weights of inedible offals like blood, feather, skin, shank, head, intestines, proventriculus, spleen, trachea, oesophagus and wings and a significant difference (P<0.05) in the weights of inedible offals - lungs of emus between the 15 and 18 months age groups.

Table 4: Influence of age on the weights and per cent yields of inedible offals (Mean ± S.E.) of emu

Inedible offals	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Blood	1.20 ± 0.02	1.63 ± 0.01	20.33**	6.69 ± 0.14	8.24 ± 0.11	8.78**
Feather	0.41 ± 0.02	0.55 ± 0.01	6.71**	2.43 ± 0.11	2.76 ± 0.09	2.31*
Skin	2.81 ± 0.01	3.19 ± 0.01	30.32**	15.61 ± 0.21	16.12 ± 0.15	1.99NS
Shank	1.06 ± 0.02	1.38 ± 0.01	15.51**	5.92 ± 0.04	6.99 ± 0.12	8.44**
Head	0.31 ± 0.01	0.36 ± 0.01	4.76**	1.73 ± 0.03	1.79 ± 0.03	1.43NS
Lungs	0.30 ± 0.02	0.35 ± 0.01	2.37*	1.66 ± 0.09	1.74 ± 0.04	0.82*
Intestines	0.59 ± 0.02	0.70 ± 0.02	4.36**	3.31± 0.12	3.55 ± 0.09	1.51NS
Proventriculus	0.07 ± 0.00	0.15 ± 0.01	9.81**	0.39 ± 0.02	0.74 ± 0.04	7.95**
Spleen	0.03 ± 0.00	0.07 ± 0.00	11.61**	0.17 ± 0.02	0.37 ± 0.01	10.81**
Trachea	0.14 ± 0.02	0.16 ± 0.01	4.19**	0.56 ± 0.04	0.62 ± 0.05	3.25**
Oesophagus	0.12 ± 0.01	0.14 ± 0.02	6.07**	0.44 ± 0.02	0.52 ± 0.04	4.54**
Wings	0.05 ± 0.00	0.07 ± 0.00	4.47**	0.26 ± 0.02	0.33 ± 0.02	3.02**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), * * = highly significant (P<0.01), NS = Non – significant (P>0.05).**

The mean ± S.E. values for the per cent yields of inedible offals like blood, feather, skin, shank, head, lungs, intestines, proventriculus, spleen, trachea, oesophagus and wings of emus of 15 and 18 months age group were 6.69 ± 0.14 and 8.24 ± 0.11, 2.43 ± 0.11 and 2.76 ± 0.09, 15.61 ± 0.21 and 16.12 ± 0.15, 5.92 ± 0.04 and 6.99 ± 0.12, 1.73 ± 0.03 and 1.79 ± 0.03, 1.66 ± 0.09 and 1.74 ± 0.04, 3.31± 0.12 and 3.55 ± 0.09, 0.39 ± 0.02 and 0.74 ± 0.04, 0.17 ± 0.02 and 0.37 ± 0.01, 0.56 ± 0.04 and 0.62 ± 0.05, 0.44 ± 0.02 and 0.52 ± 0.04, 0.26 ± 0.02 and 0.33 ± 0.02 respectively.

The test of significance revealed a highly significant difference ($P<0.01$) in the the per cent yields of inedible offals like blood, shank, proventriculus, spleen, trachea, oesophagus and wings, a significant difference ($P<0.05$) in the per cent yields of feather and lungs and a non significant difference ($P>0.05$) in the per cent yields of inedible offals - skin, head and intestines of emus between the 15 and 18 months age groups.

4.1.5 Weights and yields of cut up parts

Mean values and standard error for the weights (kg) and per cent yields of cut up parts like neck, rib, breast, drumstick, thigh, loin, rump and fat from emus of 15 and 18 month age groups are presented in Table 5 along with test of significance.

The mean ± S.E. values for the weights of cut up parts like neck, rib, breast, drumstick, thigh, loin, rump and fat of emus of 15 and 18 months age groups were 0.47 ± 0.01 and 0.63 ± 0.01, 0.42 ± 0.01 and 0.48 ± 0.02, 0.12 ± 0.01 and 0.17 ± 0.01, 4.41 ± 0.01 and 4.22 ± 0.03, 4.31 ± 0.07 and 4.04 ± 0.06, 0.74 ± 0.02 and 0.85 ± 0.01, 1.05 ± 0.01 and 0.87 ± 0.01, 3.54 ± 0.08 and 4.68 ± 0.08 respectively.

Table 5: Influence of age on the yields of different cut up parts (Mean ± S.E.) of emu

Cut up parts (Kg)	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Neck	0.47 ± 0.01	0.63 ± 0.01	15.80**	1.67 ± 0.02	2.07 ± 0.01	17.34**
Rib	0.42 ± 0.01	0.48 ± 0.02	2.94*	1.52 ± 0.02	1.57 ± 0.06	0.89NS
Breast	0.12 ± 0.01	0.17 ± 0.01	6.27*	0.42 ± 0.02	0.55 ± 0.02	4.62**
Drumstick	4.41 ± 0.01	4.22 ± 0.03	17.35**	15.61 ± 0.15	13.78 ± 0.09	8.15**
Thigh	4.31 ± 0.07	4.04 ± 0.06	4.92**	14.84 ± 0.19	13.21 ± 0.14	6.98**
Loin	0.74 ± 0.02	0.85 ± 0.01	5.09**	3.07 ± 0.05	2.42 ± 0.02	4.17**
Rump	1.05 ± 0.01	0.87 ± 0.01	18.79**	3.77 ± 0.02	2.85 ± 0.04	19.56**
Fat	3.54 ± 0.08	4.68 ± 0.08	4.06**	12.71 ± 0.20	15.30 ± 0.25	4.97**

No. of samples – 8, means bearing different superscripts differ significantly.

* * = highly significant (P<0.01), NS = Non - significant (P>0.05)

The test of significance revealed a highly significant difference (P<0.01) in the mean weights of cut up parts like neck, drumstick, thigh, loin, rump and fat and a significant difference (P<0.05) in the weights of rib (kg) and breast (kg) of emus of 15 and 18 months age groups.

The mean ± S.E. values for the per cent yields of cut up parts like neck, rib, breast, drumstick, thigh, loin, rump and fat of emus of 15 and 18 months age groups were 1.67 ± 0.02 and 2.07 ± 0.01, 1.52 ± 0.02 and 1.57 ± 0.06, 0.42 ± 0.02 and 0.55 ± 0.02, 15.61 ± 0.15 and 13.78 ± 0.09, 14.84 ± 0.19 and 13.21 ± 0.14, 3.07 ± 0.05 and 2.42 ± 0.02, 3.77 ± 0.02 and 2.85 ± 0.04, 12.71 ± 0.20 and 15.30 ± 0.25 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the mean values of per cent yields of cut up parts like neck, breast, drumstick, thigh, loin, rump and fat and a non significant difference (P>0.05) in the mean values of cut up part rib of the emus of 15 and 18 months age groups.

4.2 Physico chemical parameters

4.2.1 pH

The mean ± S.E. values of pH of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed mean pH values of 5.66 ± 0.01 and 5.65 ± 0.01 on 0 day, 5.61 ± 0.01 and 5.65 ± 0.01 on 1st day (chiller stored), 5.46 ± 0.01 and 5.43 ± 0.01 on 2nd day, 5.52 ± 0.00 and 5.53 ± 0.00 on 7th day (freezer stored) respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in pH between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance did not reveal any significant difference (P>0.05) in pH between emus of the two age groups stored on 0,1st, 2nd and 7th day.

Table 6: Influence of age on physico – chemical properties (mean ± SE) of emu meat at different storage periods

Physico – chemical properties	Storage period (days) → Age (months) ↓	0 day	1st day	2nd day	7th day	F - value
pH	15	$5.66^{d} \pm 0.01$	$5.61^{c} \pm 0.01$	$5.46^{a} \pm 0.01$	$5.52^{b} \pm 0.00$	717.09^{**}
	18	$5.65^{d} \pm 0.01$	$5.58^{c} \pm 0.01$	$5.43^{a} \pm 0.01$	$5.53^{b} \pm 0.00$	560.02^{**}
	t - value	1.55^{NS}	2.02^{NS}	1.21^{NS}	1.82^{NS}	-
WHC (cm^2)	15	$1.62^{a} \pm 0.02$	$1.84^{b} \pm 0.03$	$2.27^{c} \pm 0.02$	$2.82^{d} \pm 0.01$	642.14^{**}
	18	$1.76^{a} \pm 0.04$	$1.95^{b} \pm 0.04$	$2.16^{c} \pm 0.02$	$2.74^{d} \pm 0.01$	538.99^{**}
	t - value	10.76^{**}	13.65^{**}	13.74^{**}	13.48^{**}	-
R – value	15	$1.06^{a} \pm 0.00$	$1.22^{b} \pm 0.00$	$1.28^{c} \pm 0.00$	$1.24^{b} \pm 0.00$	224.56^{**}
	18	$1.09^{a} \pm 0.00$	$1.24^{b} \pm 0.00$	$1.29^{c} \pm 0.00$	$1.23^{b} \pm 0.00$	76.80^{**}
	t - value	1.83^{NS}	1.09^{NS}	1.69^{NS}	1.13^{NS}	-
ERV (ml)	15	$20.64^{a} \pm 0.14$	$21.89^{b} \pm 0.26$	$23.66^{c} \pm 0.22$	$23.88^{d} \pm 0.22$	$2,03.94^{**}$
	18	$20.59^{a} \pm 0.11$	$21.12^{b} \pm 0.15$	$23.37^{c} \pm 0.29$	$23.76^{d} \pm 0.22$	248.17^{**}
	t - value	2.17^{NS}	2.57^{NS}	1.69^{NS}	1.87^{NS}	-
TBA No.(mg . malonal / Kg)	15	$0.56^{a} \pm 0.00$	$0.53^{b} \pm 0.004$	$0.67^{c} \pm 0.00$	$0.71^{d} \pm 0.00$	115.47^{**}
	18	$0.67^{a} \pm 0.00$	$0.65^{b} \pm 0.00$	$0.69^{c} \pm 0.00$	$0.73^{d} \pm 0.00$	131.07^{**}
	t - value	2.74^{*}	5.89^{*}	6.27^{*}	4.68^{*}	-
TV (mg/100g)	15	$1.10^{a} \pm 0.003$	$1.16^{b} \pm 0.021$	$1.22^{c} \pm 0.006$	$1.24^{d} \pm 0.009$	74.86^{**}
	18	$1.09^{a} \pm 0.007$	$1.15^{b} \pm 0.005$	$1.23^{c} \pm 0.010$	$1.26^{d} \pm 0.006$	65.37^{**}
	t - value	1.39^{NS}	1.10^{NS}	0.95^{NS}	1.04^{NS}	-
Fibre diameter (µm)	15	$14.35^{d} \pm 0.07$	$13.65^{c} \pm 0.10$	$12.82^{b} \pm 0.10$	$11.29^{a} \pm 0.09$	195.55^{**}
	18	$17.27^{d} \pm 0.06$	$15.73^{c} \pm 0.04$	$14.33^{b} \pm 0.05$	$12.14^{a} \pm 0.05$	180.08^{**}
	t - value	29.09^{**}	18.92^{**}	14.30^{**}	7.90^{**}	-
Sarcomere length (µm)	15	$2.92^{a} \pm 0.03$	$3.14^{b} \pm 0.04$	$3.30^{c} \pm 0.05$	$3.57^{d} \pm 0.04$	41.18^{**}
	18	$2.23^{a} \pm 0.05$	$2.68^{b} \pm 0.04$	$2.95^{c} \pm 0.04$	$3.20^{d} \pm 0.05$	81.08^{**}
	t - value	10.64^{**}	7.78^{**}	9.58^{**}	6.79^{**}	-
MFI	15	$720.75^{d} \pm 2.37$	$708.25^{c} \pm 5.29$	$695.88^{b} \pm 2.23$	$672.88^{a} \pm 1.43$	40.93^{**}
	18	$737.38^{d} \pm 2.63$	$725.13^{c} \pm 2.36$	$710.00^{b} \pm 2.62$	$695.38^{a} \pm 1.73$	59.48^{**}
	t - value	14.69^{**}	12.91^{**}	14.11^{**}	10.01^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

* = significant ($P<0.05$), ** = highly significant ($P<0.01$), NS = Non – significant ($P>0.05$).

The mean ± S.E. values of pH of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 7 along with analysis of variance and test of significance.

The mean ± S.E. values of pH of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 5.66 ± 0.01 and 5.65 ± 0.01, 5.63 ± 0.01 and 5.64 ± 0.01, 5.61 ± 0.00 and 5.63 ± 0.01 respectively. The analysis of variance revealed a highly significant difference ($P<0.01$) between pH of different muscle regions. The test of significance also indicated a highly significant difference in the pH of drumstick, thigh and breast muscles between the two age groups.

4.2.2 Water holding capacity

The mean ± S.E. values of water holding capacity (cm^2) of emus of 15 and 18 months age groups for different periods (0, 1^{st}, 2^{nd} and 7^{th} day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed a mean water holding capacity values of 1.62 ± 0.02 and 1.76 ± 0.04 on 0 day, 1.84 ± 0.03 and 1.95 ± 0.04 on 1^{st} day (chiller stored), 2.27 ± 0.02 and 2.16 ± 0.03 on 2^{nd} day, 2.82 ± 0.01 and 2.74 ± 0.01on 7^{th} day (freezer stored) respectively.

The analysis of variance revealed a highly significant difference ($P<0.01$) in water holding capacity between emus of the two age groups for different periods (0, 1^{st}, 2^{nd} and 7^{th} day). The test of significance also revealed a highly significant difference ($P<0.01$) in water holding capacity between emus of the two age groups on 0, 1^{st} 2^{nd} and 7^{th} day.

The mean ± S.E. values of water holding capacity (cm^2) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 7 along with analysis of variance and test of significance.

The mean ± S.E. values of water holding capacity of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 1.62 ± 0.03 and 1.76 ± 0.05, 1.54 ± 0.05 and 1.70 ± 0.04, 1.41 ±0.03 and 1.51 ± 0.05 respectively. The analysis of variance revealed a highly significant difference ($P<0.01$) between water holding capacity of different muscle regions. The test of significance also indicated a highly significant difference ($P<0.01$) in the water holding capacity of drumstick, thigh and breast muscles between the two age groups.

4.2.3 Extract Release Volume

The mean ± S.E. values of extract release volume (ml) of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emu of 15 and 18 months age groups showed mean extract release volume values of 20.64 ± 0.14 and 20.59 ± 0.11, 21.89 ± 0.26 and 21.12 ± 0.15, 23.66 ± 0.22 and 23.37 ± 0.29, 23.88 ± 0.22 and 23.76 ± 0.22 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) in extract release volume values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance did not reveal any significant difference ($P >0.05$) in extract release volume values between emus of the two age groups stored on 0,1st, 2nd and 7th day.

4.2.4 R – value

The mean ± S.E. values of R- values of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed mean R- values of 1.06 ± 0.00 and 1.09 ± 0.00 on 0 day, 1.22 ± 0.00 and 1.24 ± 0.00 on

1st day (chiller stored), 1.28 ± 0.00 and 1.29± 0.00 on 2nd day, 1.24 ± 0.00 and 1.23 ± 0.00 on 7th day (freezer stored) respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in R –values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance did not reveal any significant difference (P>0.05) in R - values between emus of the two age groups on 0, 1st, 2nd and 7th day.

4.2.5 Fibre Diameter

The mean ± S.E. values of fibre diameter (µm) of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed mean fibre diameter values of 14.35 ± 0.07 and 17.27 ± 0.06 , 13.65 ± 0.10 and 15.73 ± 0.04, 12.82 ± 0.10 and 13.33 ± 0.05, 11.29 ± 0.09 and 12.14 ± 0.05 respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in fibre diameter values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance also revealed a highly significant difference (P<0.01) in fibre diameter values between emus of the two age groups stored on 0, 1st, 2nd and 7th day.

4.2.6 Sarcomere length

The mean ± S.E. values of sarcomere length (µm) of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed mean sarcomere lengths of 2.92 ± 0.03 and 2.23 ± 0.05, 3.14 ± 0.04 and 2.68 ± 0.04, 3.30 ± 0.05 and 2.95 ± 0.04, 3.57 ± 0.04 and 3.20 ± 0.05 respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in sarcomere lengths values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance also revealed a highly significant difference (P<0.01) in sarcomere length values between emus of the two age groups stored on 0, 1st, 2nd and 7th day.

4.2.7 Myofibrillar fragmentation index

The mean ± S.E. values of myofibrillar fragmentation index of emus of the 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of the 15 and 18 months age groups showed mean myofibrillar fragmentation index of 720.75 ± 2.37 and 737.38 ± 2.63, 708.25 ± 5.29 and 725.13 ± 2.36, 695.88 ± 2.23 and 710.00 ± 2.62, 672.88 ± 1.43 and 695.38 ± 1.73 respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in myofibrillar fragmentation index values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance also revealed a highly significant difference (P<0.01) in myofibrillar fragmentation index values between emus of the two age groups stored on 0, 1st, 2nd and 7th day.

4.2.8 Shear force value

The mean ± S.E. values of shear force values of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 7 along with analysis of variance and test of significance.

The mean ± S.E. values of shear force values of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 3.11 ± 0.01 and 3.27 ± 0.06, 2.79 ± 0.01 and 2.88 ± 0.01, 2.53 ± 0.03 and 2.76 ± 0.02 respectively.

Table 7: Influence of age and muscle region on the pH, Water holding capacity, Myoglobin content, Shear force value and Collagen content of emu meat

Physico – chemical properties	Muscle region→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
pH	15	$5.66^{c} \pm 0.01$	$5.63^{b} \pm 0.01$	$5.61^{a} \pm 0.00$	8.67^{**}
	18	$5.65^{c} \pm 0.01$	$5.64^{b} \pm 0.01$	$5.63^{a} \pm 0.01$	8.08^{**}
	t - value	4.02^{**}	5.38^{**}	6.22^{**}	-
WHC (cm^2)	15	$1.62^{c} \pm 0.03$	$1.54^{b} \pm 0.04$	$1.41^{a} \pm 0.02$	25.95^{**}
	18	$1.76^{c} \pm 0.05$	$1.70^{b} \pm 0.04$	$1.51^{a} \pm 0.03$	27.09^{**}
	t - value	38.30^{**}	12.53^{*}	17.85^{**}	-
Myoglobin content	15	$1.23^{c} \pm 0.03$	$1.10^{b} \pm 0.02$	$0.64^{a} \pm 0.03$	171.45^{**}
	18	$1.35^{c} \pm 0.01$	$1.27^{b} \pm 0.01$	$1.12^{a} \pm 0.02$	87.50^{**}
	t - value	6.73^{**}	8.27^{**}	15.14^{**}	-
SFV (kg/cm^2)	15	$3.11^{c} \pm 0.01$	$2.79^{b} \pm 0.01$	$2.53^{a} \pm 0.03$	296.68^{**}
	18	$3.27^{c} \pm 0.06$	$2.88^{b} \pm 0.07$	$2.76^{a} \pm 0.02$	44.4^{**}
	t - value	21.72^{**}	10.43^{**}	11.25^{**}	-
Collagen(mg/g)	15	$7.27^{c} \pm 0.01$	$7.12^{b} \pm 0.01$	$6.61^{a} \pm 0.03$	301.23^{**}
	18	$8.23^{c} \pm 0.24$	$7.88^{b} \pm 0.02$	$6.68^{a} \pm 0.02$	974.83^{**}
	t - value	31.89^{**}	29.75^{**}	7.03^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

* = significant ($P<0.05$), ** = highly significant ($P<0.01$),

NS = Non – significant ($P>0.05$).

The analysis of variance revealed a highly significant difference (P<0.01) between shear force values of different muscle regions. The test of significance also indicated a highly significant difference (P<0.01) in the shear force values between the drumstick, thigh and breast muscles of the two age groups.

4.2.9 Collagen content

The mean ± S.E. values of collagen content of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 7 along with analysis of variance and test of significance.

The mean ± S.E. values of collagen content of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 7.27 ± 0.01 and 8.23 ± 0.24, 7.12 ± 0.01 and 7.88 ± 0.02, 6.61 ± 0.03 and 6.68 ± 0.02 respectively.

The analysis of variance revealed a highly significant difference (P<0.01) between collagen content of different muscle regions. The test of significance also indicated a highly significant difference (P<0.01) in the collagen content between the drumstick, thigh and breast muscle regions of the two age groups.

4.2.10 Texture profile analysis

The mean ± S.E. values of texture profile [hardness (kgf), springiness (mm), cohesiveness, gumminess (N) and chewiness (kgf.mm)] of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 8 along with analysis of variance and test of significance.

Hardness

The mean ± S.E. values of hardness (kgf) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 53.62 ± 0.19 and 55.14 ± 0.33, 52.44 ± 0.12 and 54.40 ± 0.39, 51.47 ± 0.14 and 53.61 ± 0.48 respectively.

Table 8. Influence of age on the textural characteristics of different muscle regions of emu meat

Texture Profile	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Hardness (kgf)	**15**	$53.62^{c} \pm 0.19$	$52.44^{b} \pm 0.12$	$51.47^{a} \pm 0.14$	48.06^{**}
	18	$55.14^{b} \pm 0.33$	$54.40^{b} \pm 0.39$	$53.61^{a} \pm 0.48$	3.52^{*}
	t - value	13.88^{**}	14.78^{**}	14.23^{**}	-
Springiness (mm)	**15**	$0.64^{c} \pm 0.01$	$0.41^{b} \pm 0.01$	$0.32^{a} \pm 0.02$	113.18^{**}
	18	$0.94^{c} \pm 0.01$	$0.87^{b} \pm 0.01$	$0.83^{a} \pm 0.02$	16.25^{**}
	t - value	15.62^{**}	24.29^{**}	2.21^{**}	-
Cohesiveness (ratio)	**15**	$0.33^{c} \pm 0.02$	$0.31^{b} \pm 0.02$	$0.27^{a} \pm 0.01$	5.91^{**}
	18	$0.43^{c} \pm 0.02$	$0.42^{b} \pm 0.01$	$0.38^{a} \pm 0.02$	7.38^{**}
	t - value	10.79^{**}	10.57^{**}	12.53^{*}	-
Gumminess (N)	**15**	$17.95^{c} \pm 0.91$	$16.72^{b} \pm 0.60$	$13.88^{a} \pm 0.63$	8.12^{**}
	18	$24.12^{c} \pm 0.02$	$22.83^{b} \pm 0.72$	$20.61^{a} \pm 0.60$	7.57^{**}
	t - value	10.35^{**}	10.97^{**}	11.14^{**}	-
Chewiness (kgf/mm)	**15**	$11.62^{c} \pm 0.67$	$6.87^{b} \pm 0.29$	$4.47^{a} \pm 0.45$	53.25^{**}
	18	$22.65^{c} \pm 0.63$	$20.02^{b} \pm 0.82$	$17.16^{a} \pm 0.84$	12.62^{**}
	t - value	16.00^{**}	23.05^{**}	21.61^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

* = significant ($P<0.05$), ** = highly significant ($P<0.01$), NS = Non – significant ($P>0.05$).

The analysis of variance revealed highly significant difference (P<0.01) between hardness of different muscle regions. The test of significance indicated a highly significant difference (P<0.01) in the hardness of drumstick, thigh and breast muscle regions between the two age groups.

Springiness

The mean ± S.E. values of springiness (mm) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 0.64 ± 0.01and 0.94 ± 0.01, 0.41 ± 0.01 and 0.87 ± 0.01, 0.32 ± 0.02 and 0.83 ± 0.02.

The analysis of variance revealed highly significant difference (P<0.01) between springiness of different muscle regions. The test of significance indicated a highly significant difference (P<0.01) in the springiness of drumstick, thigh and breast muscle regions between the two age groups.

Cohesiveness

The mean ± S.E. values of cohesiveness of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 0.33 ± 0.02 and 0.43 ± 0.02, 0.31 ± 0.02 and 0.42 ± 0.01, 0.27 ± 0.01and 0.38 ± 0.02 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between cohesiveness of different muscle regions. The test of significance indicated a highly significant difference (P<0.01) in the cohesiveness of drumstick, thigh and breast muscle regions between the two age groups.

Gumminess

The mean ± S.E. values of gumminess (N) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 17.95 ± 0.91and 24.12 ± 0.02, 16.72 ± 0.60 and 22.83 ± 0.72, 13.88 ± 0.63 and 20.61 ± 0.60 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between gumminess of different muscle regions. The test of significance indicated a

highly significant difference (P<0.01) in the gumminess of drumstick, thigh and breast muscle regions between the two age groups.

Chewiness

The mean ± S.E. values of chewiness (kgf.mm) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 11.62 ± 0.67 and 22.65 ± 0.63, 6.87 ± 0.29 and 20.02 ± 0.82, 4.47 ± 0.45 and 17.16 ± 0.84 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between chewiness of different muscle regions. The test of significance indicated a highly significant difference (P<0.01) in the chewiness of drumstick, thigh and breast muscle regions was observed in the chewiness of muscle regions between the two age groups.

4.2.11 Thiobarbituric acid number

The mean ± S.E. values of thiobarbituric acid (TBA) number (mg of malonaldehyde / kg) of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed mean TBA values of 0.56 ± 0.00 and 0.67 ± 0.00, 0.53 ± 0.00 and 0.65 ± 0.00, 0.67 ± 0.00 and 0.69 ± 0.00, 0.71 ± 0.00 and 0.73 ± 0.00 respectively.

The analysis of variance revealed a highly significant difference (P<0.01) in thiobarbituric acid number values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance revealed a significant difference (P<0.05) in thiobarbituric acid number values between emus of the two age groups on 0, 1st , 2nd and 7th day.

4.2.12 Tyrosine value

The mean ± S.E. values of tyrosine value (mg/100g) of emus of 15 and 18 months age groups for different periods (0, 1st, 2nd and 7th day) are presented in Table 6 along with analysis of variance and test of significance.

The muscles of emus of 15 and 18 months age groups showed a mean tyrosine values of 1.10 ± 0.01 and 1.09 ± 0.01, 1.16 ± 0.01 and 1.15± 0.01, 1.22 ± 0.02 and 1.23 ± 0.01, 1.24 ± 0.00 and 1.26 ± 0.00 respectively.

The analysis of variance revealed a highly significant difference ($P<0.01$) tyrosine values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day). The test of significance did not reveal any significant difference ($P>0.05$) in tyrosine values between emus of the two age groups for different periods (0, 1st, 2nd and 7th day).

4.2.13 Myoglobin content

The mean ± S.E. values of myoglobin content of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 7 along with analysis of variance and test of significance.

The mean ± S.E. values of myoglobin contentof drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 1.23 ± 0.025 and 1.35 ± 0.010, 1.10 ± 0.019 and 1.27 ± 0.009, 0.64 ± 0.026 and 1.12 ± 0.017 respectively.

The analysis of variance revealed a highly significant difference ($P<0.01$) between myoglobin content of different muscle regions. The test of significance also revealed a highly significant difference ($P<0.01$) in the myoglobin content between the drumstick, thigh and breast muscles of the two age groups.

Table 9. Influence of age on the spectrophotometric assay of colour (mean ± SE) of different muscle regions of emu meat

Hunter colour variables	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Lightness (L)	15	$31.27^{a} \pm 0.23$	$32.76^{b} \pm 0.24$	$44.84^{c} \pm 0.80$	215.57^{**}
	18	$28.36^{a} \pm 0.39$	$31.16^{b} \pm 0.01$	$43.87^{c} \pm 0.95$	191.06^{**}
	t - value	6.34^{**}	11.96^{**}	18.50^{**}	-
Redness (a*)	15	$11.12^{a} \pm 0.02$	$11.62^{b} \pm 0.20$	$13.18^{c} \pm 0.24$	34.18^{**}
	18	$11.76^{a} \pm 0.04$	$13.33^{b} \pm 0.17$	$14.94^{c} \pm 0.35$	47.13^{**}
	t - value	6.41^{**}	6.32^{**}	7.77^{**}	-
Yellowness (b*)	15	$5.78^{a} \pm 0.04$	$6.83^{b} \pm 0.02$	$7.90^{c} \pm 0.04$	715.18^{**}
	18	$6.84^{a} \pm 0.03$	$7.39^{b} \pm 0.06$	$8.91^{c} \pm 0.02$	562.20^{**}
	t - value	6.77^{**}	4.08^{**}	20.84^{**}	-
Hue	15	$0.54^{a} \pm 0.02$	$0.56^{a} \pm 0.01$	$0.59^{b} \pm 0.01$	5.32^{*}
	18	$0.45^{a} \pm 0.00$	$0.47^{a} \pm 0.01$	$0.49^{b} \pm 0.01$	8.08^{**}
	t - value	17.13^{**}	7.15^{**}	8.79^{**}	-
Chroma	15	$13.11^{a} \pm 0.03$	$14.98^{b} \pm 0.15$	$16.90^{c} \pm 0.33$	101.07^{**}
	18	$13.05^{a} \pm 0.02$	$13.78^{b} \pm 0.15$	$15.91^{c} \pm 0.19$	80.61^{**}
	t - value	6.32^{**}	5.51^{**}	4.55^{*}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly ($P<0.05$), .

* = significant ($P<0.05$) ** = highly significant ($P<0.01$), NS = Non – significant ($P>0.05$).

4.2.14 Spectrophotometric assay of meat colour

The mean ± S.E. values of Hunter colour scores (L^*- lightness, a^* - redness, b^* - yellowness, hue (intensity of colour) and chroma (intensity of brightness) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 9 along with analysis of variance and test of significance.

Lightness (L^*)

The mean ± S.E. values of lightness **(L^*)** of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 31.27 ± 0.23 and 28.36 ± 0.39, 32.76 ± 0.24 and 31.16 ± 0.01, 44.84 ± 0.80 and 43.87 ± 0.95 respectively.

The analysis of variance revealed a highly significant difference ($P<0.01$) between lightness **(L^*)** of different muscle regions. The test of significance also indicated a highly significant difference ($P<0.01$) in the lightness **(L^*)** of drumstick, thigh and breast muscle regions between the two age groups.

Redness (a^*)

The mean ± S.E. values of redness (a^*) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 11.12 ± 0.02 and 11.76 ± 0.04, 11.62 ± 0.20 and 13.33 ± 0.17, 13.18 ± 0.24 and 14.94 ± 0.35 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) between redness (a^*) of different muscle regions. The test of significance indicated a highly significant difference ($P<0.01$) in the redness (a^*) of drumstick, thigh and breast muscle regions between the two age groups.

Yellowness (b^*)

The mean ± S.E. values of yellowness (b^*) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 5.78 ± 0.04 and 6.84 ± 0.03, 6.83 ± 0.02 and 7.39 ± 0.06, 7.90 ± 0.04 and 8.91 ± 0.02 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between yellowness (b^*) of different muscle regions. The test of significance indicated a highly significant difference (P<0.01) in the yellowness (b^*) of drumstick, thigh and breast muscle regions between the two age groups.

Hue

The mean ± S.E. values of hue of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 0.54 ± 0.01 and 0.45 ± 0.00, 0.56 ± 0.01 and 0.47 ± 0.01, 0.59 ± 0.02 and 0.49 ± 0.01 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between hue of different muscle regions. The test of significance also indicated a highly significant difference (P<0.01) in the hue of drumstick, thigh and breast muscle regions between the two age groups.

Chroma

The mean ± S.E. values of chroma of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups were 13.11 ± 0.03 and 13.05 ± 0.02, 14.98 ± 0.15 and 13.78 ± 0.15, 16.90 ± 0.33 and 15.91 ± 0.19 respectively.

The analysis of variance revealed highly significant difference (P<0.01) between chroma of different muscle regions. The test of significance also indicated a highly significant difference (P<0.01) in the chroma value of different muscle regions between the two age groups.

4.3 Nutritional Quality

4.3.1 Proximate composition

Mean values and standard error for the proximate composition (moisture, protein, fat and total ash) and cholesterol content of emu meat from emus of 15 and 18 month age group are presented in Table 10 along with test of significance.

The mean ± S.E. values for the proximate composition (moisture, protein, fat and total ash) and cholesterol content of emus of 15 and 18 months age group were 72.23 ±0.13 and 71.72 ± 0.15, 24.18 ± 0.09 and 23.94 ± 0.15, 2.62 ± 0.07 and 3.26 ± 0.05, 1.08 ± 0.01 and 1.21 ± 0.01 and 24.42 ± 0.18 and 26.13 ± 0.11 respectively.

The test of significance revealed a highly significant difference ($P<0.01$) in the cholesterol, fat and total ash content, significant difference ($P<0.05$) in the moisture content and a non significant difference ($P>0.05$) in the protein content of emus of 15 and 18 months age groups.

4.3.2. Proximate composition of emu meat, beef and chicken meat

Mean values and standard error for the proximate composition (moisture, protein, fat and total ash) and cholesterol content of emu meat, beef and chicken meat are presented in Table 11 along with analysis of variance.

The mean ± S.E. values for the proximate composition (moisture, protein, fat and total ash) and cholesterol content of emu meat, beef and chicken meat are 72.23 ± 0.13, 71.02 ± 0.27, and 75.59 ± 0.43, 24.18 ± 0.08, 20.67 ± 0.08 and 20.09 ± 0.11, 2.62 ± 0.65, 6.76 ± 0.19 and 4.24 ± 0.15, 1.13 ± 0.02, 1.03 ± 0.01 and 0.93 ± 0.01, 24.42 ± 0.18, 57.13 ± 0.63 and 79.31 ± 0.52 respectively.

The analysis of variance revealed a highly significant difference ($P<0.01$) between the proximate composition and cholesterol content of emu meat, beef and chicken meat.

4.3.3 Mineral content

The mean ± S.E. values of mineral content (ppm) of drumstick, thigh and breast muscle regions of emus of 15 and 18 months age groups are presented in the Table 12 along with analysis of variance and test of significance.

Table 10: Influence of age on the proximate composition and cholesterol content (mean ± SE) of emu meat

Parameters	Age (months)		t - value
	15	18	
Proximate composition (%)			
Moisture	72.23 ± 0.13	71.72 ± 0.15	2.52*
Protein	24.07 ± 0.09	23.81 ± 0.15	1.35NS
Fat	2.62 ± 0.07	3.26 ± 0.05	7.68**
Total Ash	1.08 ± 0.01	1.21 ± 0.01	9.98**
Cholesterol content (mg/100g)			
Cholesterol	24.42 ± 0.18	26.13 ± 0.11	8.06**

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant (P<0.05), ** = highly significant (P<0.01),

NS = Non – significant (P>0.05).

Table 11: Comparison of proximate composition and cholesterol content of emu meat, beef and chicken meat

Parameters	Emu	Beef	Chicken	F - value
Proximate composition (%)				
Moisture	$72.23^{a} \pm 0.13$	$71.64^{a} \pm 0.27$	$75.14^{b} \pm 0.43$	31.36^{**}
Protein	$24.07^{c} \pm 0.08$	$20.67^{b} \pm 0.08$	$20.09^{a} \pm 0.11$	982.53^{**}
Fat	$2.62^{a} \pm 0.65$	$6.76^{c} \pm 0.19$	$4.04^{c} \pm 0.15$	$2,699.61^{**}$
Total ash	$1.13^{c} \pm 0.02$	$1.03^{b} \pm 0.01$	$0.73^{a} \pm 0.01$	65.375^{**}
Cholesterol content (mg/100g)				
Cholesterol	$24.42^{a} \pm 0.18$	$57.13^{b} \pm 0.63$	$79.31^{c} \pm 0.52$	$1,699.08^{**}$

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant ($P<0.05$), ** = highly significant ($P<0.01$),

NS = Non – significant ($P>0.05$).

The analysis of variance revealed a highly significant difference ($P<0.01$) between mineral content of different muscle regions. The test of significance also indicated a highly significant difference ($P<0.01$) in the mineral content of drumstick, thigh and breast muscles between the two age groups.

4.3.4 Fatty acid profile

Mean values and standard error for the fatty acid composition (saturated fatty acids – myristic, palmitic, stearic and arachidic acid, mono unsaturated fatty acids – palmitoleic and oleic acid, poly unsaturated fatty acids – linoleic, linolenic and docosohexanoic acids) of emu meat from emus of 15 and 18 month age group are presented in Table 13 along with test of significance.

The mean ± S.E. values for the fatty acid composition (saturated fatty acids – myristic, palmitic, stearic and arachidic acid, mono unsaturated fatty acids – palmitoleic and oleic acid, poly unsaturated fatty acids – linoleic, linolenic and docosohexanoic acids) of emu meat from emus of 15 and 18 months age group were 0.71 ± 0.01 and 0.98 ± 0.02, 19.05 ± 0.35 and 22.03 ± 0.35, 10.13 ± 0.33 and 14.34 ± 0.28, 0.14 ± 0.01 and 0.21 ± 0.01, 4.03 ± 0.19 and 3.53 ± 0.17, 33.97 ± 0.44 and 30.36 ± 0.44, 17.45 ± 0.11 and 15.94 ± 0.15, 4.32 ± 0.01 and 2.97 ± 0.01, 0.73 ± 0.01 and 0.46± 0.01 respectively.

The test of significance revealed a highly significant difference ($P<0.01$) in the myristic, palmitic, stearic, arachidic acid, palmitoleic, oleic, linoloeic, linolenic and docosohexanoic acid contents of emu meat from emus of 15 and 18 months age groups.

Table 12: Influence of age on the mineral content of different muscle regions of emu meat

Mineral content (ppm)	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Aluminium	15	$0.50^{c} \pm 0.01$	$0.40^{b} \pm 0.00$	$0.37^{a} \pm 0.00$	397.16^{**}
	18	$0.53^{a} \pm 0.00$	$0.46^{a} \pm 0.00$	$0.42^{a} \pm 0.00$	$1,268.11^{**}$
	t - value	4.13^{**}	40.65^{**}	25.52^{**}	-
Boron	15	$0.17^{c} \pm 0.00$	$0.15^{b} \pm 0.00$	$0.12^{a} \pm 0.00$	939.745^{**}
	18	$0.18^{c} \pm 0.00$	$0.14^{b} \pm 0.00$	$0.11^{a} \pm 0.00$	779.20^{**}
	t - value	11.86^{**}	5.25^{**}	7.72^{**}	-
Calcium	15	$5.49^{c} \pm 0.07$	$2.45^{b} \pm 0.01$	$2.03^{a} \pm 0.06$	$1,180.18^{**}$
	18	$4.42^{c} \pm 0.04$	$3.78^{b} \pm 0.06$	$3.12^{a} \pm 0.11$	72.02^{**}
	t - value	13.18^{**}	23.61^{**}	8.48^{**}	-
Cobolt	15	$0.001^{c} \pm 0.00$	$0.001^{b} \pm 0.00$	$0.001^{a} \pm 0.00$	47.33^{**}
	18	$0.002^{c} \pm 0.00$	$0.002^{b} \pm 0.00$	$0.001^{a} \pm 0.00$	58.09^{**}
	t - value	8.49^{**}	9.51^{**}	11.10^{**}	-
Chromium	15	$0.10^{c} \pm 0.00$	$0.09^{b} \pm 0.00$	$0.09^{a} \pm 0.00$	140.19^{**}
	18	$0.11^{c} \pm 0.00$	$0.10^{b} \pm 0.00$	$0.09^{a} \pm 0.00$	93.18^{**}
	t - value	4.82^{**}	12.32^{**}	5.49^{**}	-
Copper	15	$0.16^{c} \pm 0.00$	$0.12^{b} \pm 0.00$	$0.12^{a} \pm 0.00$	$1,315.52^{**}$
	18	$0.17^{c} \pm 0.00$	$0.16^{b} \pm 0.00$	$0.14^{a} \pm 0.00$	352.53^{**}
	t - value	11.86^{**}	30.42^{**}	21.60^{**}	-
Iron	15	$4.99^{c} \pm 0.11$	$4.27^{b} \pm 0.05$	$3.27^{a} \pm 0.05$	143.61^{**}
	18	$5.20^{c} \pm 0.06$	$4.72^{b} \pm 0.02$	$3.82^{a} \pm 0.02$	341.07^{**}
	t - value	5.76^{**}	9.43^{**}	10.98^{**}	-
Magnesium	15	$24.50^{c} \pm 0.38$	$23.41^{b} \pm 0.11$	$21.13^{a} \pm 0.011$	271.85^{**}
	18	$21.68^{c} \pm 0.12$	$21.18^{b} \pm 0.03$	$17.57^{a} \pm 0.03$	81.25^{**}
	t - value	23.94^{**}	62.12^{**}	61.32^{**}	-
Manganese	15	$0.04^{c} \pm 0.01$	$0.02^{a} \pm 0.00$	$0.03^{b} \pm 0.01$	8.45^{**}
	18	$0.08^{c} \pm 0.00$	$0.07^{b} \pm 0.00$	$0.05^{a} \pm 0.00$	41.82^{**}
	t - value	16.87^{**}	30.82^{**}	8.64^{**}	-
Sodium	15	$62.14^{c} \pm 0.05$	$57.86^{b} \pm 0.11$	$54.63^{a} \pm 0.06$	115.80^{*}
	18	$51.43^{c} \pm 0.01$	$46.15^{b} \pm 0.01$	$41.11^{a} \pm 0.01$	74.26^{**}
	t - value	103.08^{**}	192.63^{**}	182.91^{**}	-
Zinc	15	$3.92^{c} \pm 0.02$	$3.11^{b} \pm 0.01$	$2.88^{a} \pm 0.03$	947.04^{**}
	18	$3.51^{c} \pm 0.00$	$3.18^{b} \pm 0.05$	$1.92^{a} \pm 0.00$	169.58^{**}
	t - value	54.47^{**}	15.05^{**}	23.51^{**}	-

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant ($P<0.05$), ** = highly significant ($P<0.01$), NS = Non – significant ($P>0.05$).

Table 13: Influence of age on the fatty acid profile of emu meat of two different age groups

Fatty acid type	Fatty acid (%)	Age (months)		t - value
		15	18	
Saturated fatty acids (SFA)	Myristic Acid (C14:0)	0.71 ± 0.01	0.98 ± 0.02	14.49**
	Palmitic Acid (C16:0)	19.05 ± 0.35	22.03 ± 0.35	8.66**
	Stearic Acid (C18:0)	10.13 ± 0.33	14.34 ± 0.28	17.15**
	Arachidic Acid (C20:0)	0.14 ± 0.01	0.21 ± 0.01	12.09**
Mono unsaturated fatty acids (MUFA)	Palmitoleic Acid (C16:1)	4.03 ± 0.19	3.53 ± 0.17	6.56**
	Oleic Acid (C18:1) *	33.97 ± 0.44	30.36 ± 0.44	9.88**
Poly unsaturated fatty acids (PUFA)	Linoleic Acid (C18:2) **	17.45 ± 0.11	15.94 ± 0.15	11.71**
	Linolenic Acid (C18:3)**	4.32 ± 0.01	2.97 ± 0.01	7.61**
	Docosohexanoic Acid (C22:6) *	0.73 ± 0.01	0.46± 0.01	11.20**

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).

* = unsaturated fatty acid,

** = Essential fatty acid

The saturated fatty acids (myristic, palmitic, stearic and arachidic) were observed to be more in the meat from emus of 18 months age group. The mono unsaturated (palmitoleic and oleic) and the poly unsaturated (linoleic, linolenic and docosohexanoic) were observed to be more in the meat from emus of 15 months age group.

4.3.5 Amino acid composition

Mean values and standard error for the amino acid composition in g/100g (alanine, arginine, aspartic, glycine, glutamic, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, serine, threonine, tyrosine and valine) of emu meat from the emus of 15 and 18 month age group are presented in Table 14 along with test of significance.

The mean ± S.E. values for the amino acid composition (alanine, arginine, aspartic, glycine, glutamic, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, serine, threonine, tyrosine and valine) of emu meat from emus of 15 and 18 months age group were 6.08 ± 0.00 and 6.04 ± 0.01, 6.45 ± 0.00 and 6.27 ± 0.01, 9.44 ± 0.00 and 9.29 ± 0.01, 5.02 ± 0.00 and 5.06 ± 0.00, 15.32 ± 0.01 and 16.12 ± 0.01, 4.61 ± 0.00 and 3.46 ± 0.01, 5.12 ± 0.00 and 5.05 ± 0.00, 8.44 ± 0.00 and 8.37 ± 0.01, 9.27 ± 0.00 and 9.19 ± 0.01, 0.01 ± 2.94 and 0.01 ± 2.86, 4.53 ± 0.00 and 4.49 ± 0.00, 4.45 ± 0.00 and 4.47 ± 0.00, 4.52 ± 0.01 and 4.34 ± 0.00,4.04 ± 0.00 and 4.03 ± 0.01, 5.03 ± 0.00 and 5.02 ± 0.00 respectively.

The test of significance revealed a highly significant difference ($P<0.01$) in the arginine, aspartic acid, glutamic acid, histidine, isoleucine, leucine, lysine, methionine, phenylalanine and threonine contents and a non significant

difference (P>0.05) in the alanine, glycine, serine, tyrosine and valine contents of emus of 15 and 18 months age groups.

Table 14: Influence of age on the amino acid profile of emu meat of two different age groups

Amino acid (g / 100g)	Age (months)		t - value
	15	18	
Alanine	6.08 ± 0.00	6.04 ± 0.01	2.90^{NS}
Arginine*	6.45 ± 0.00	6.27 ± 0.01	7.24^{**}
Aspartic	9.44 ± 0.00	9.29 ± 0.01	8.62^{**}
Glycine	5.02 ± 0.00	5.06 ± 0.00	0.33^{NS}
Glutamic	15.32 ± 0.01	16.12 ± 0.01	7.91^{**}
Histidine*	4.61 ± 0.00	3.46 ± 0.01	8.57^{**}
Isoleucine*	5.12 ± 0.00	5.05 ± 0.00	11.83^{**}
Leucine*	8.44 ± 0.00	8.37 ± 0.01	13.14^{**}
Lysine*	9.27 ± 0.00	9.19 ± 0.01	7.53^{**}
Methionine*	2.94 ± 0.00	2.86 ± 0.00	9.95^{**}
Phenylalanine*	4.53 ± 0.00	4.49 ± 0.00	12.56^{**}
Serine	4.45 ± 0.00	4.47 ± 0.00	0.46^{NS}
Threonine*	4.52 ± 0.01	4.34 ± 0.00	12.41^{**}
Tyrosine*	4.04 ± 0.00	4.03 ± 0.01	1.09^{NS}
Valine*	5.03 ± 0.00	5.02 ± 0.00	1.50^{NS}

* = Essential amino acid

No. of samples – 8, means bearing different superscripts differ significantly.

* = significant (P<0.05), ** = highly significant (P<0.01),

NS = Non – significant (P>0.05).

Essential amino acids like arginine, isoleucine, leucine, lysine, phenylalanine and threonine were found to be more in the emu meat from emus of 15 months age group.

4.4 Organoleptic quality

Mean values and standard error for the organoleptic scores (appearance, flavor, tenderness, juiciness and overall palatability) of emu meat of the two age groups are presented in Table 15 along with test of significance.

4.4.1 Appearance

The mean ± S.E. values for the appearance scores of emu meat from emu of 15 and 18 months age group were 7.43 ± 0.065 and 6.19 ± 0.103 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the appearance scores between the two age groups.

4.4.2 Flavour

The mean ± S.E. values for the flavour scores of emu meat from emus of 15 and 18 months age group were 7.33 ± 0.041 and 6.39 ± 0.072 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the flavour scores between the two age groups.

4.4.3 Tenderness

The mean ± S.E. values for the tenderness scores of emu meat from emus of 15 and 18 months age group were 8.11 ± 0.091 and 7.56 ± 0.049 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the tenderness scores between the two age groups.

4.4.4 Juiciness

The mean ± S.E. values for the juiciness scores of emu meat from emus of 15 and 18 months age group were 8.48 ± 0.079 and 7.28 ± 0.056 respectively.

Table 15: Effect of age on the organoleptic scores (mean ± SE) of emu meat

Sensory attributes	Age (months)		t - value
	15	18	
Appearance	7.43 ± 0.065	6.19 ± 0.103	10.20**
Flavour	7.33 ± 0.041	6.39 ± 0.072	13.74**
Tenderness	8.11 ± 0.091	7.56 ± 0.049	5.28**
Juiciness	8.48 ± 0.079	7.28 ± 0.056	12.35**
Overall palatability	7.84 ± 0.029	6.81 ±0.032	23.52**

No. of samples – 8, means bearing different superscripts differ significantly.

** = highly significant (P<0.01).

The test of significance revealed a highly significant difference (P<0.01) in the juiciness scores between the two age groups.

4.4.5 Overall palatability

The mean ± S.E. values for the overall palatability scores of emu meat from emus of 15 and 18 months age group were 7.84 ± 0.029 and 6.81 ± 0.032 respectively.

The test of significance revealed a highly significant difference (P<0.01) in the overall palatability scores between the two age groups.

4.5 Microbiological quality

Mean values and standard error for the microbiological qualities (total viable count, salmonella and coliform count) of emu meat from emus of 15 and 18 month age group are presented in Table 16 along with test of significance.

4.5.1 Total viable count

The mean ± S.E. values for the total viable count of emu meat from emus of 15 and 18 months age group were 2.41± 0.077 and 2.56 ± 0.065 respectively.

The test of significance revealed that there was no significant difference (P> 0.05) in the total viable counts of emu meat from emus of 15 and 18 months age groups.

4.5.2 Salmonella count

There were no salmonella detected in the meat samples from emus of both 15 and 18 months age groups.

4.5.3 Coliforms count

There were no coliforms detected in the meat samples from emus of both 15 and 18 months age groups.

Table 16: Influence of age on the microbiological quality (mean ± SE) of emu meat

Microbiological quality (cfu/g)	Age (months)		t - value
	15	18	
Total Plate Count	2.41± 0.077	2.56 ± 0.065	1.466^{NS}
Salmonella	ND	ND	-
Coliforms	ND	ND	-

No. of samples – 8, means bearing different superscripts differ significantly.

NS = Non – significant (P>0.05).

4.6 Value added products

4.6.1 Emulsion stability

The mean ± S.E. values of emulsion stability (%) of sausages and nuggets made from emu meat, beef and chicken meat were 84.24 ± 0.12, 82.19 ± 0.13 and

85.91 ± 0.17, 84.32 ± 0.14, 82.60 ± 0.17 and 86.28 ± 0.18 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) in the emulsion stability of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance did not reveal any significant difference ($P<0.01$) in the emulsion stability of the sausages and nuggets made from emu meat, beef and chicken meat.

4.6.2 Product yield

The mean ± S.E. values of product yield (%) of sausages and nuggets made from emu meat, beef and chicken meat were 92.88 ± 0.17, 90.89 ± 0.31 and

93.52 ± 0.25, 95.68 ± 0.14, 92.74 ± 0.11and 96.40 ± 0.17 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) in the product yields of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance also indicated a highly significant difference ($P<0.01$) in the product yields of the sausages and nuggets made from emu meat, beef and chicken meat.

4.7 Sensory evaluation

The mean ± S.E. values of Sensory evaluation scores (appearance, flavour, tenderness, juiciness and overall palatability) of sausages and nuggets made from emu meat, beef and chicken meat are presented in Table 19 along with analysis of variance and test of significance.

Table 17: Comparison of the physico – chemical and sensory evaluation scores of emu meat, beef and chicken meat products

Parameter	Treatment	Emu	Beef	Chicken	F - value
Physico – chemical properties					
Emulsion stability (%)	**Sausages**	$84.24^{b} \pm 0.123$	$82.19^{a} \pm 0.129$	$85.91^{c} \pm 0.169$	108.32^{**}
	Nuggets	$84.32^{b} \pm 0.144$	$82.60^{a} \pm 0.165$	$86.28^{c} \pm 0.181$	86.47^{**}
	t - value	0.43^{NS}	2.79^{NS}	3.52^{NS}	-
Product yield (%)	**Sausages**	$92.88^{b} \pm 0.176$	$90.89^{a} \pm 0.305$	$93.52^{c} \pm 0.252$	8.36^{**}
	Nuggets	$95.68^{b} \pm 0.144$	$92.74^{a} \pm 0.108$	$96.40^{c} \pm 0.169$	5.82^{**}
	t - value	12.3^{**}	5.73^{**}	6.41^{**}	-
Sensory attributes					
Appearance	**Sausages**	$7.18^{b} \pm 0.04$	$6.42^{a} \pm 0.07$	$7.53^{c} \pm 0.07$	7.51^{**}
	Nuggets	$7.22^{b} \pm 0.05$	$6.60^{a} \pm 0.00$	$7.60^{c} \pm 0.05$	16.25^{**}
	t - value	2.03^{NS}	6.45^{**}	3.64^{**}	-
Flavour	**Sausages**	$7.15^{a} \pm 0.05$	$7.22^{b} \pm 0.06$	$7.40^{c} \pm 0.05$	13.77^{**}
	Nuggets	$6.60^{a} \pm 0.08$	$7.20^{b} \pm 0.05$	$7.37^{c} \pm 0.07$	48.36^{**}
	t - value	8.64^{**}	0.31^{NS}	5.61^{**}	-
Tenderness	**Sausages**	$7.10^{b} \pm 0.00$	$6.60^{a} \pm 0.07$	$7.51^{c} \pm 0.04$	18.24^{**}
	Nuggets	$6.40^{b} \pm 0.05$	$6.25^{a} \pm 0.07$	$7.20^{c} \pm 0.08$	39.51^{**}
	t - value	9.56^{**}	9.98^{**}	12.28^{**}	-
Juiciness	**Sausages**	$6.52^{b} \pm 0.08$	$6.45^{a} \pm 0.05$	$7.17^{c} \pm 0.05$	9.17^{**}
	Nuggets	$6.63^{b} \pm 0.05$	$6.42^{a} \pm 0.01$	$7.01^{c} \pm 0.07$	53.21^{**}
	t - value	1.66^{NS}	0.90^{NS}	1.91^{NS}	-
Overall palatability	**Sausages**	$6.55^{a} \pm 0.03$	$6.56^{a} \pm 0.02$	$7.11^{b} \pm 0.03$	81.45^{**}
	Nuggets	$6.92^{a} \pm 0.03$	$6.91^{a} \pm 0.03$	$7.28^{b} \pm 0.02$	17.56^{**}
	t - value	5.70^{**}	6.81^{**}	6.24^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

* = significant (P<0.05), ** = highly significant (P<0.01),NS = Non – significant (P>0.05),

Appearance

The mean ± S.E. values of appearance scores of sausages and nuggets made from emu meat, beef and chicken meat were 7.18 ± 0.04, 6.42 ± 0.07 and 7.53 ± 0.07, 7.22 ± 0.05, 6.60 ± 0.01 and 7.60 ± 0.05 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) in the appearance scores of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance indicated a highly significant difference ($P<0.01$) in the appearance scores of the sausages and nuggets made from beef and chicken meat and there was no significant difference ($P>0.05$) noticed in the appearance scores of the sausages and nuggets made from emu meat.

Flavour

The mean ± S.E. values of flavour scores of sausages and nuggets made from emu meat, beef and chicken meat were 7.15 ± 0.05, 7.22 ± 0.06 and 7.40 ± 0.05, 6.60 ± 0.08, 7.20 ± 0.05 and 7.37 ± 0.07 respectively.

The analysis of variance revealed highly significant difference ($P<0.01$) in the flavour scores of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance indicated a highly significant difference ($P<0.01$) in the flavour scores of the sausages and nuggets made from emu meat and chicken meat and no significant difference ($P<0.05$) was noticed in the flavour scores of the sausages and nuggets made from beef.

Tenderness

The mean ± S.E. values of tenderness scores of sausages and nuggets made from emu meat, beef and chicken meat were 7.10 ± 0.00, 6.60 ± 0.07 and 7.51 ± 0.04, 6.40 ± 0.05, 6.25 ± 0.07 and 7.20 ± 0.08 respectively.

The analysis of variance revealed highly significant difference (P<0.01) in the tenderness scores of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance also indicated a highly significant difference (P<0.01) in the tenderness scores of the sausages and nuggets made from emu meat, beef and chicken meat.

Juiciness

The mean ± S.E. values of juiciness scores of sausages and nuggets made from emu meat, beef and chicken meat were 6.52 ± 0.08, 6.45 ± 0.05 and 7.17 ± 0.05, 6.63 ± 0.05, 6.42 ± 0.01 and 7.01 ± 0.07 respectively.

The analysis of variance revealed highly significant difference (P<0.01) in the juiciness scores of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance did not indicate any significant difference (P>0.05) in the juiciness scores of the sausages and nuggets made from emu meat, beef and chicken meat.

Overall palatability

The mean ± S.E. values of overall palatability of sausages and nuggets made from emu meat, beef and chicken meat were 6.55 ± 0.03, 6.56 ± 0.02 and 7.11 ± 0.03, 6.92 ± 0.03, 6.91 ± 0.03 and 7.28 ± 0.02 respectively.

The analysis of variance revealed highly significant difference (P<0.01) in the overall palatability scores of the sausages and nuggets made from emu meat, beef and chicken meat. The test of significance also indicated a highly significant difference (P<0.01) in the overall palatability scores of the sausages and nuggets made from emu meat, beef and chicken meat.

4.8 Histological studies

Hematoxylin and Eosin stained muscle tissue sections of emu, beef and chicken were studied. The longitudinal and cross sections showing the muscle fibres of emu, beef and chicken revealed that the fibre diameters of emu tissues (12 – 14µm) were similar to that of chicken (11 - 13µm) than beef (23 - 30µm).

Table 1: Influence of age on the carcass characteristics (Mean ± S.E.) of emu

Carcass characteristics	Age (months)		t - value
	15	18	
Live weight (Kg)	27.85 ± 0.29	30.62 ± 0.12	8.86**
Carcass weight (Kg)	18.12 ± 0.22	20.81± 0.17	9.44**
Chilled Carcass weight (kg)	16.65 ± 0.27	19.59 ± 0.17	9.07**
Chiller Shrinkage (%)	8.14 ± 0.73	5.86 ± 0.28	2.91*
Dressing per cent (%)	65.06 ± 0.41	67.95 ± 0.34	5.40**
Meat : Bone ratio	3.02 ± 0.04	2.65 ± 0.03	5.52**
Drip loss (%)	1.71 ± 0.989	2.32 ± 0.76	0.36NS
Cooking loss (%)	31.19 ± 0.12	30.74 ± 0.15	3.15**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), * * = highly significant (P<0.01).**

Table 2: Influence of age on the carcass measurements (Mean ± S.E.) of emu

Carcass measurements (cm)	Age (months)		t - value
	15	18	
Carcass length	46.43 ± 0.34	52.17 ± 0.32	12.32**
Neck	56.97 ± 0.24	62.35 ± 0.81	6.35**
Shank	53.26 ± 0.28	56.57 ± 0.30	8.15**
Trachea	67.95 ± 0.33	75.78 ± 0.39	15.32**
Oesophagus	71.33 ± 0.43	80.34 ± 0.38	15.66**
Intestine	437.45 ± 1.91	452.12 ± 1.19	6.53**
Chest girth	67.34 ± 0.19	72.06 ± 0.37	11.23**
Gigot length	43.08 ± 0.52	53.20 ± 0.33	16.60**
Gigot width	27.87 ± 0.19	33.86 ± 0.18	22.55**

No. of samples – 8, means bearing different superscripts differ significantly.

*** * = highly significant (P<0.01).**

Table 3: Influence of age on the weights and per cent yields of edible offals (Mean ± S.E.) of emu

Edible offals (Kg)	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Heart	0.38 ± 0.02	0.42 ± 0.01	6.75^{**}	1.35 ± 0.02	1.39 ± 0.02	1.74^{NS}
Liver	0.40 ± 0.02	0.44 ± 0.00	5.95^{**}	1.43 ± 0.02	1.45 ± 0.02	0.82^{NS}
Kidney	0.18 ± 0.02	0.23 ± 0.01	6.13^{**}	0.65 ± 0.02	0.74 ± 0.01	3.53^{**}
Gizzard	0.33 ± 0.02	0.37 ± 0.01	2.97^{*}	1.18 ± 0.02	1.22 ± 0.03	1.14^{NS}

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), * * = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 4: Influence of age on the weights and per cent yields of inedible offals (Mean ± S.E.) of emu

Inedible offals	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Blood	1.20 ± 0.02	1.63 ± 0.01	20.33**	6.69 ± 0.14	8.24 ± 0.11	8.78**
Feather	0.41 ± 0.02	0.55 ± 0.01	6.71**	2.43 ± 0.11	2.76 ± 0.09	2.31*
Skin	2.81 ± 0.01	3.19 ± 0.01	30.32**	15.61 ± 0.21	16.12 ± 0.15	1.99NS
Shank	1.06 ± 0.02	1.38 ± 0.01	15.51**	5.92 ± 0.04	6.99 ± 0.12	8.44**
Head	0.31 ± 0.01	0.36 ± 0.01	4.76**	1.73 ± 0.03	1.79 ± 0.03	1.43NS
Lungs	0.30 ± 0.02	0.35 ± 0.01	2.37*	1.66 ± 0.09	1.74 ± 0.04	0.82*
Intestines	0.59 ± 0.02	0.70 ± 0.02	4.36**	3.31± 0.12	3.55 ± 0.09	1.51NS
Proventriculus	0.07 ± 0.00	0.15 ± 0.01	9.81**	0.39 ± 0.02	0.74 ± 0.04	7.95**
Spleen	0.03 ± 0.00	0.07 ± 0.00	11.61**	0.17 ± 0.02	0.37 ± 0.01	10.81**
Trachea	0.14 ± 0.02	0.16 ± 0.01	4.19**	0.56 ± 0.04	0.62 ± 0.05	3.25**
Oesophagus	0.12 ± 0.01	0.14 ± 0.02	6.07**	0.44 ± 0.02	0.52 ± 0.04	4.54**
Wings	0.05 ± 0.00	0.07 ± 0.00	4.47**	0.26 ± 0.02	0.33 ± 0.02	3.02**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), * * = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 5: Influence of age on the yields of different cut up parts (Mean ± S.E.) of emu

Cut up parts (Kg)	Weights (Kg)		t - value	Yield (%)		t - value
	Age (months)			Age (months)		
	15	18		15	18	
Neck	0.47 ± 0.01	0.63 ± 0.01	15.80**	1.67 ± 0.02	2.07 ± 0.01	17.34**
Rib	0.42 ± 0.01	0.48 ± 0.02	2.94*	1.52 ± 0.02	1.57 ± 0.06	0.89NS
Breast	0.12 ± 0.01	0.17 ± 0.01	6.27*	0.42 ± 0.02	0.55 ± 0.02	4.62**
Drumstick	4.41 ± 0.01	4.22 ± 0.03	17.35**	15.61 ± 0.15	13.78 ± 0.09	8.15**
Thigh	4.31 ± 0.07	4.04 ± 0.06	4.92**	14.84 ± 0.19	13.21 ± 0.14	6.98**
Loin	0.74 ± 0.02	0.85 ± 0.01	5.09**	3.07 ± 0.05	2.42 ± 0.02	4.17**
Rump	1.05 ± 0.01	0.87 ± 0.01	18.79**	3.77 ± 0.02	2.85 ± 0.04	19.56**
Fat	3.54 ± 0.08	4.68 ± 0.08	4.06**	12.71 ± 0.20	15.30 ± 0.25	4.97**

No. of samples – 8, means bearing different superscripts differ significantly.

*** * = highly significant (P<0.01), NS = Non - significant (P>0.05).**

Table 6: Influence of age on physico – chemical properties (mean ± SE) of emu meat at different storage periods

Physico – chemical properties	Storage period (days) → Age (months) ↓	0 day	1st day	2nd day	7th day	F - value
pH	15	$5.66^{d} \pm 0.01$	$5.61^{c} \pm 0.01$	$5.46^{a} \pm 0.01$	$5.52^{b} \pm 0.00$	717.09^{**}
	18	$5.65^{d} \pm 0.01$	$5.58^{c} \pm 0.01$	$5.43^{a} \pm 0.01$	$5.53^{b} \pm 0.00$	560.02^{**}
	t - value	1.55^{NS}	2.02^{NS}	1.21^{NS}	1.82^{NS}	-
WHC (cm^2)	15	$1.62^{a} \pm 0.02$	$1.84^{b} \pm 0.03$	$2.27^{c} \pm 0.02$	$2.82^{d} \pm 0.01$	642.14^{**}
	18	$1.76^{a} \pm 0.04$	$1.95^{b} \pm 0.04$	$2.16^{c} \pm 0.02$	$2.74^{d} \pm 0.01$	538.99^{**}
	t - value	10.76^{**}	13.65^{**}	13.74^{**}	13.48^{**}	-
R – value	15	$1.06^{a} \pm 0.00$	$1.22^{b} \pm 0.00$	$1.28^{c} \pm 0.00$	$1.24^{b} \pm 0.00$	224.56^{**}
	18	$1.09^{a} \pm 0.00$	$1.24^{b} \pm 0.00$	$1.29^{c} \pm 0.00$	$1.23^{b} \pm 0.00$	76.80^{**}
	t - value	1.83^{NS}	1.09^{NS}	1.69^{NS}	1.13^{NS}	-
ERV (ml)	15	$20.64^{a} \pm 0.14$	$21.89^{b} \pm 0.26$	$23.66^{c} \pm 0.22$	$23.88^{d} \pm 0.22$	$2,03.94^{**}$
	18	$20.59^{a} \pm 0.11$	$21.12^{b} \pm 0.15$	$23.37^{c} \pm 0.29$	$23.76^{d} \pm 0.22$	248.17^{**}
	t - value	2.17^{NS}	2.57^{NS}	1.69^{NS}	1.87^{NS}	-
TBA No.(mg . malonal / Kg)	15	$0.56^{a} \pm 0.00$	$0.53^{b} \pm 0.004$	$0.67^{c} \pm 0.00$	$0.71^{d} \pm 0.00$	115.47^{**}
	18	$0.67^{a} \pm 0.00$	$0.65^{b} \pm 0.00$	$0.69^{c} \pm 0.00$	$0.73^{d} \pm 0.00$	131.07^{**}
	t - value	2.74^{*}	5.89^{*}	6.27^{*}	4.68^{*}	-
TV (mg/100g)	15	$1.10^{a} \pm 0.003$	$1.16^{b} \pm 0.021$	$1.22^{c} \pm 0.006$	$1.24^{d} \pm 0.009$	74.86^{**}
	18	$1.09^{a} \pm 0.007$	$1.15^{b} \pm 0.005$	$1.23^{c} \pm 0.010$	$1.26^{d} \pm 0.006$	65.37^{**}
	t - value	1.39^{NS}	1.10^{NS}	0.95^{NS}	1.04^{NS}	-
Fibre diameter (µm)	15	$14.35^{d} \pm 0.07$	$13.65^{c} \pm 0.10$	$12.82^{b} \pm 0.10$	$11.29^{a} \pm 0.09$	195.55^{**}
	18	$17.27^{d} \pm 0.06$	$15.73^{c} \pm 0.04$	$14.33^{b} \pm 0.05$	$12.14^{a} \pm 0.05$	180.08^{**}
	t - value	29.09^{**}	18.92^{**}	14.30^{**}	7.90^{**}	-
Sarcomere length (µm)	15	$2.92^{a} \pm 0.03$	$3.14^{b} \pm 0.04$	$3.30^{c} \pm 0.05$	$3.57^{d} \pm 0.04$	41.18^{**}
	18	$2.23^{a} \pm 0.05$	$2.68^{b} \pm 0.04$	$2.95^{c} \pm 0.04$	$3.20^{d} \pm 0.05$	81.08^{**}
	t - value	10.64^{**}	7.78^{**}	9.58^{**}	6.79^{**}	-
MFI	15	$720.75^{d} \pm 2.37$	$708.25^{c} \pm 5.29$	$695.88^{b} \pm 2.23$	$672.88^{a} \pm 1.43$	40.93^{**}
	18	$737.38^{d} \pm 2.63$	$725.13^{c} \pm 2.36$	$710.00^{b} \pm 2.62$	$695.38^{a} \pm 1.73$	59.48^{**}
	t - value	14.69^{**}	12.91^{**}	14.11^{**}	10.01^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 7: Influence of age and muscle region on the pH, Water holding capacity, Myoglobin content, Shear force value and Collagen content of emu meat

Physico – chemical properties	Muscle region→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
pH	15	$5.66^{c} \pm 0.01$	$5.63^{b} \pm 0.01$	$5.61^{a} \pm 0.00$	8.67^{**}
	18	$5.65^{c} \pm 0.01$	$5.64^{b} \pm 0.01$	$5.63^{a} \pm 0.01$	8.08^{**}
	t - value	4.02^{**}	5.38^{**}	6.22^{**}	-
WHC (cm^2)	15	$1.62^{c} \pm 0.03$	$1.54^{b} \pm 0.04$	$1.41^{a} \pm 0.02$	25.95^{**}
	18	$1.76^{c} \pm 0.05$	$1.70^{b} \pm 0.04$	$1.51^{a} \pm 0.03$	27.09^{**}
	t - value	38.30^{**}	12.53^{*}	17.85^{**}	-
Myoglobin content	15	$1.23^{c} \pm 0.03$	$1.10^{b} \pm 0.02$	$0.64^{a} \pm 0.03$	171.45^{**}
	18	$1.35^{c} \pm 0.01$	$1.27^{b} \pm 0.01$	$1.12^{a} \pm 0.02$	87.50^{**}
	t - value	6.73^{**}	8.27^{**}	15.14^{**}	-
SFV (kg/cm^2)	15	$3.11^{c} \pm 0.01$	$2.79^{b} \pm 0.01$	$2.53^{a} \pm 0.03$	296.68^{**}
	18	$3.27^{c} \pm 0.06$	$2.88^{b} \pm 0.07$	$2.76^{a} \pm 0.02$	44.4^{**}
	t - value	21.72^{**}	10.43^{**}	11.25^{**}	-
Collagen(mg/g)	15	$7.27^{c} \pm 0.01$	$7.12^{b} \pm 0.01$	$6.61^{a} \pm 0.03$	301.23^{**}
	18	$8.23^{c} \pm 0.24$	$7.88^{b} \pm 0.02$	$6.68^{a} \pm 0.02$	974.83^{**}
	t - value	31.89^{**}	29.75^{**}	7.03^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 8. Influence of age on the spectrophotometric assay of colour (mean ± SE) of different muscle regions of emu meat

Hunter colour variables	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Lightness (L)	15	$31.27^{a} \pm 0.23$	$32.76^{b} \pm 0.24$	$44.84^{c} \pm 0.80$	215.57^{**}
	18	$28.36^{a} \pm 0.39$	$31.16^{b} \pm 0.01$	$43.87^{c} \pm 0.95$	191.06^{**}
	t - value	6.34^{**}	11.96^{**}	18.50^{**}	-
Redness (a*)	15	$11.12^{a} \pm 0.02$	$11.62^{b} \pm 0.20$	$13.18^{c} \pm 0.24$	34.18^{**}
	18	$11.76^{a} \pm 0.04$	$13.33^{b} \pm 0.17$	$14.94^{c} \pm 0.35$	47.13^{**}
	t - value	6.41^{**}	6.32^{**}	7.77^{**}	-
Yellowness (b*)	15	$5.78^{a} \pm 0.04$	$6.83^{b} \pm 0.02$	$7.90^{c} \pm 0.04$	715.18^{**}
	18	$6.84^{a} \pm 0.03$	$7.39^{b} \pm 0.06$	$8.91^{c} \pm 0.02$	562.20^{**}
	t - value	6.77^{**}	4.08^{**}	20.84^{**}	-
Hue	15	$0.54^{a} \pm 0.02$	$0.56^{a} \pm 0.01$	$0.59^{b} \pm 0.01$	5.32^{*}
	18	$0.45^{a} \pm 0.00$	$0.47^{a} \pm 0.01$	$0.49^{b} \pm 0.01$	8.08^{**}
	t - value	17.13^{**}	7.15^{**}	8.79^{**}	-
Chroma	15	$13.11^{a} \pm 0.03$	$14.98^{b} \pm 0.15$	$16.90^{c} \pm 0.33$	101.07^{**}
	18	$13.05^{a} \pm 0.02$	$13.78^{b} \pm 0.15$	$15.91^{c} \pm 0.19$	80.61^{**}
	t - value	6.32^{**}	5.51^{**}	4.55^{*}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly (P<0.05), .

*** = significant (P<0.05) ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 9. Influence of age on the textural characteristics of different muscle regions of emu meat

Texture Profile	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Hardness (kgf)	**15**	$53.62^{c} \pm 0.19$	$52.44^{b} \pm 0.12$	$51.47^{a} \pm 0.14$	48.06^{**}
	18	$55.14^{b} \pm 0.33$	$54.40^{b} \pm 0.39$	$53.61^{a} \pm 0.48$	3.52^{*}
	t - value	13.88^{**}	14.78^{**}	14.23^{**}	-
Springiness (mm)	**15**	$0.64^{c} \pm 0.01$	$0.41^{b} \pm 0.01$	$0.32^{a} \pm 0.02$	113.18^{**}
	18	$0.94^{c} \pm 0.01$	$0.87^{b} \pm 0.01$	$0.83^{a} \pm 0.02$	16.25^{**}
	t - value	15.62^{**}	24.29^{**}	2.21^{**}	-
Cohesiveness (ratio)	**15**	$0.33^{c} \pm 0.02$	$0.31^{b} \pm 0.02$	$0.27^{a} \pm 0.01$	5.91^{**}
	18	$0.43^{c} \pm 0.02$	$0.42^{b} \pm 0.01$	$0.38^{a} \pm 0.02$	7.38^{**}
	t - value	10.79^{**}	10.57^{**}	12.53^{*}	-
Gumminess (N)	**15**	$17.95^{c} \pm 0.91$	$16.72^{b} \pm 0.60$	$13.88^{a} \pm 0.63$	8.12^{**}
	18	$24.12^{c} \pm 0.02$	$22.83^{b} \pm 0.72$	$20.61^{a} \pm 0.60$	7.57^{**}
	t - value	10.35^{**}	10.97^{**}	11.14^{**}	-
Chewiness (kgf/mm)	**15**	$11.62^{c} \pm 0.67$	$6.87^{b} \pm 0.29$	$4.47^{a} \pm 0.45$	53.25^{**}
	18	$22.65^{c} \pm 0.63$	$20.02^{b} \pm 0.82$	$17.16^{a} \pm 0.84$	12.62^{**}
	t - value	16.00^{**}	23.05^{**}	21.61^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 10: Influence of age on the proximate composition and cholesterol content (mean ± SE) of emu meat

Parameters	Age (months)		t - value
	15	18	
Proximate composition (%)			
Moisture	72.23 ± 0.13	71.72 ± 0.15	2.52*
Protein	24.07 ± 0.09	23.81 ± 0.15	1.35NS
Fat	2.62 ± 0.07	3.26 ± 0.05	7.68**
Total Ash	1.08 ± 0.01	1.21 ± 0.01	9.98**
Cholesterol content (mg/100g)			
Cholesterol	24.42 ± 0.18	26.13 ± 0.11	8.06**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 11: Comparison of proximate composition and cholesterol content of emu meat, beef and chicken meat

Parameters	Emu	Beef	Chicken	F - value
Proximate composition (%)				
Moisture	$72.23^{a} \pm 0.13$	$71.64^{a} \pm 0.27$	$75.14^{b} \pm 0.43$	31.36^{**}
Protein	$24.07^{c} \pm 0.08$	$20.67^{b} \pm 0.08$	$20.09^{a} \pm 0.11$	982.53^{**}
Fat	$2.62^{a} \pm 0.65$	$6.76^{c} \pm 0.19$	$4.04^{c} \pm 0.15$	$2,699.61^{**}$
Total ash	$1.13^{c} \pm 0.02$	$1.03^{b} \pm 0.01$	$0.73^{a} \pm 0.01$	65.375^{**}
Cholesterol content (mg/100g)				
Cholesterol	$24.42^{a} \pm 0.18$	$57.13^{b} \pm 0.63$	$79.31^{c} \pm 0.52$	$1,699.08^{**}$

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 12: Mean ± (S. E.) of the amino acid profile of emu meat of two different age groups

Amino acid (g / 100g)	Age (months)		t - value
	15	18	
Alanine	6.08 ± 0.00	6.04 ± 0.01	2.90^{NS}
Arginine*	6.45 ± 0.00	6.27 ± 0.01	7.24^{**}
Aspartic	9.44 ± 0.00	9.29 ± 0.01	8.62^{**}
Glycine	5.02 ± 0.00	5.06 ± 0.00	0.33^{NS}
Glutamic	15.32 ± 0.01	16.12 ± 0.01	7.91^{**}
Histidine*	4.61 ± 0.00	3.46 ± 0.01	8.57^{**}
Isoleucine*	5.12 ± 0.00	5.05 ± 0.00	11.83^{**}
Leucine*	8.44 ± 0.00	8.37 ± 0.01	13.14^{**}
Lysine*	9.27 ± 0.00	9.19 ± 0.01	7.53^{**}
Methionine*	2.94 ± 0.00	2.86 ± 0.00	9.95^{**}
Phenylalanine*	4.53 ± 0.00	4.49 ± 0.00	12.56^{**}
Serine	4.45 ± 0.00	4.47 ± 0.00	0.46^{NS}
Threonine*	4.52 ± 0.01	4.34 ± 0.00	12.41^{**}
Tyrosine*	4.04 ± 0.00	4.03 ± 0.01	1.09^{NS}
Valine*	5.03 ± 0.00	5.02 ± 0.00	1.50^{NS}

*** = Essential amino acid**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 13: Mean ± (S. E.) of the fatty acid profile of emu meat of two different age groups

Fatty acid type	Fatty acid (%)	Age (months)		t - value
		15	18	
Saturated fatty acids (SFA)	Myristic Acid (C14:0)	0.71 ± 0.01	0.98 ± 0.02	14.49**
	Palmitic Acid (C16:0)	19.05 ± 0.35	22.03 ± 0.35	8.66**
	Stearic Acid (C18:0)	10.13 ± 0.33	14.34 ± 0.28	17.15**
	Arachidic Acid (C20:0)	0.14 ± 0.01	0.21 ± 0.01	12.09**
Mono unsaturated fatty acids (MUFA)	Palmitoleic Acid (C16:1)	4.03 ± 0.19	3.53 ± 0.17	6.56**
	Oleic Acid (C18:1) *	33.97 ± 0.44	30.36 ± 0.44	9.88**
Poly unsaturated fatty acids (PUFA)	Linoleic Acid (C18:2) **	17.45 ± 0.11	15.94 ± 0.15	11.71**
	Linolenic Acid (C18:3)**	4.32 ± 0.01	2.97 ± 0.01	7.61**
	Docosohexanoic Acid (C22:6) *	0.73 ± 0.01	0.46± 0.01	11.20**

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

*** = unsaturated fatty acid,**

**** = Essential fatty acid**

Table 14: Influence of age on the mineral content of different muscle regions of emu meat

Mineral content (ppm)	Muscle type→ Age (months) ↓	Drumstick	Thigh	Breast	F - value
Aluminium	15	$0.50^{c} \pm 0.01$	$0.40^{b} \pm 0.00$	$0.37^{a} \pm 0.00$	397.16^{**}
	18	$0.53^{a} \pm 0.00$	$0.46^{a} \pm 0.00$	$0.42^{a} \pm 0.00$	$1,268.11^{**}$
	t - value	4.13^{**}	40.65^{**}	25.52^{**}	-
Boron	15	$0.17^{c} \pm 0.00$	$0.15^{b} \pm 0.00$	$0.12^{a} \pm 0.00$	939.745^{**}
	18	$0.18^{c} \pm 0.00$	$0.14^{b} \pm 0.00$	$0.11^{a} \pm 0.00$	779.20^{**}
	t - value	11.86^{**}	5.25^{**}	7.72^{**}	-
Calcium	15	$5.49^{c} \pm 0.07$	$2.45^{b} \pm 0.01$	$2.03^{a} \pm 0.06$	$1,180.18^{**}$
	18	$4.42^{c} \pm 0.04$	$3.78^{b} \pm 0.06$	$3.12^{a} \pm 0.11$	72.02^{**}
	t - value	13.18^{**}	23.61^{**}	8.48^{**}	-
Cobolt	15	$0.001^{c} \pm 0.00$	$0.001^{b} \pm 0.00$	$0.001^{a} \pm 0.00$	47.33^{**}
	18	$0.002^{c} \pm 0.00$	$0.002^{b} \pm 0.00$	$0.001^{a} \pm 0.00$	58.09^{**}
	t - value	8.49^{**}	9.51^{**}	11.10^{**}	-
Chromium	15	$0.10^{c} \pm 0.00$	$0.09^{b} \pm 0.00$	$0.09^{a} \pm 0.00$	140.19^{**}
	18	$0.11^{c} \pm 0.00$	$0.10^{b} \pm 0.00$	$0.09^{a} \pm 0.00$	93.18^{**}
	t - value	4.82^{**}	12.32^{**}	5.49^{**}	-
Copper	15	$0.16^{c} \pm 0.00$	$0.12^{b} \pm 0.00$	$0.12^{a} \pm 0.00$	$1,315.52^{**}$
	18	$0.17^{c} \pm 0.00$	$0.16^{b} \pm 0.00$	$0.14^{a} \pm 0.00$	352.53^{**}
	t - value	11.86^{**}	30.42^{**}	21.60^{**}	-
Iron	15	$4.99^{c} \pm 0.11$	$4.27^{b} \pm 0.05$	$3.27^{a} \pm 0.05$	143.61^{**}
	18	$5.20^{c} \pm 0.06$	$4.72^{b} \pm 0.02$	$3.82^{a} \pm 0.02$	341.07^{**}
	t - value	5.76^{**}	9.43^{**}	10.98^{**}	-
Magnesium	15	$24.50^{c} \pm 0.38$	$23.41^{b} \pm 0.11$	$21.13^{a} \pm 0.011$	271.85^{**}
	18	$21.68^{c} \pm 0.12$	$21.18^{b} \pm 0.03$	$17.57^{a} \pm 0.03$	81.25^{**}
	t - value	23.94^{**}	62.12^{**}	61.32^{**}	-
Manganese	15	$0.04^{c} \pm 0.01$	$0.02^{a} \pm 0.00$	$0.03^{b} \pm 0.01$	8.45^{**}
	18	$0.08^{c} \pm 0.00$	$0.07^{b} \pm 0.00$	$0.05^{a} \pm 0.00$	41.82^{**}
	t - value	16.87^{**}	30.82^{**}	8.64^{**}	-
Sodium	15	$62.14^{c} \pm 0.05$	$57.86^{b} \pm 0.11$	$54.63^{a} \pm 0.06$	115.80^{*}
	18	$51.43^{c} \pm 0.01$	$46.15^{b} \pm 0.01$	$41.11^{a} \pm 0.01$	74.26^{**}
	t - value	103.08^{**}	192.63^{**}	182.91^{**}	-
Zinc	15	$3.92^{c} \pm 0.02$	$3.11^{b} \pm 0.01$	$2.88^{a} \pm 0.03$	947.04^{**}
	18	$3.51^{c} \pm 0.00$	$3.18^{b} \pm 0.05$	$1.92^{a} \pm 0.00$	169.58^{**}
	t - value	54.47^{**}	15.05^{**}	23.51^{**}	-

No. of samples – 8, means bearing different superscripts differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01), NS = Non – significant (P>0.05).**

Table 15: Effect of age on the organoleptic scores (mean ± SE) of emu meat

Sensory attributes	Age (months)		t - value
	15	18	
Appearance	7.43 ± 0.065	6.19 ± 0.103	10.20**
Flavour	7.33 ± 0.041	6.39 ± 0.072	13.74**
Tenderness	8.11 ± 0.091	7.56 ± 0.049	5.28**
Juiciness	8.48 ± 0.079	7.28 ± 0.056	12.35**
Overall palatability	7.84 ± 0.029	6.81 ±0.032	23.52**

No. of samples – 8, means bearing different superscripts differ significantly.

**** = highly significant (P<0.01).**

Table 16: Influence of age on the microbiological quality (mean ± SE) of emu meat

Microbiological quality (cfu/g)	Age (months)		t - value
	15	18	
Total Plate Count	2.41± 0.077	2.56 ± 0.065	1.466^{NS}
Salmonella	ND	ND	-
Coliforms	ND	ND	-

No. of samples – 8, means bearing different superscripts differ significantly.

NS = Non – significant (P>0.05).

Table 19: Comparison of the physico – chemical and sensory evaluation scores of emu meat, beef and chicken meat products

Parameter	Treatment	Emu	Beef	Chicken	F - value
Physico – chemical properties					
Emulsion stability (%)	**Sausages**	$84.24^{b} \pm 0.123$	$82.19^{a} \pm 0.129$	$85.91^{c} \pm 0.169$	108.32^{**}
	Nuggets	$84.32^{b} \pm 0.144$	$82.60^{a} \pm 0.165$	$86.28^{c} \pm 0.181$	86.47^{**}
	t - value	0.43^{NS}	2.79^{NS}	3.52^{NS}	-
Product yield (%)	**Sausages**	$92.88^{b} \pm 0.176$	$90.89^{a} \pm 0.305$	$93.52^{c} \pm 0.252$	8.36^{**}
	Nuggets	$95.68^{b} \pm 0.144$	$92.74^{a} \pm 0.108$	$96.40^{c} \pm 0.169$	5.82^{**}
	t - value	12.3^{**}	5.73^{**}	6.41^{**}	-
Sensory attributes					
Appearance	**Sausages**	$7.18^{b} \pm 0.04$	$6.42^{a} \pm 0.07$	$7.53^{c} \pm 0.07$	7.51^{**}
	Nuggets	$7.22^{b} \pm 0.05$	$6.60^{a} \pm 0.00$	$7.60^{c} \pm 0.05$	16.25^{**}
	t - value	2.03^{NS}	6.45^{**}	3.64^{**}	-
Flavour	**Sausages**	$7.15^{a} \pm 0.05$	$7.22^{b} \pm 0.06$	$7.40^{c} \pm 0.05$	13.77^{**}
	Nuggets	$6.60^{a} \pm 0.08$	$7.20^{b} \pm 0.05$	$7.37^{c} \pm 0.07$	48.36^{**}
	t - value	8.64^{**}	0.31^{NS}	5.61^{**}	-
Tenderness	**Sausages**	$7.10^{b} \pm 0.00$	$6.60^{a} \pm 0.07$	$7.51^{c} \pm 0.04$	18.24^{**}
	Nuggets	$6.40^{b} \pm 0.05$	$6.25^{a} \pm 0.07$	$7.20^{c} \pm 0.08$	39.51^{**}
	t - value	9.56^{**}	9.98^{**}	12.28^{**}	-
Juiciness	**Sausages**	$6.52^{b} \pm 0.08$	$6.45^{a} \pm 0.05$	$7.17^{c} \pm 0.05$	9.17^{**}
	Nuggets	$6.63^{b} \pm 0.05$	$6.42^{a} \pm 0.01$	$7.01^{c} \pm 0.07$	53.21^{**}
	t - value	1.66^{NS}	0.90^{NS}	1.91^{NS}	-
Overall palatability	**Sausages**	$6.55^{a} \pm 0.03$	$6.56^{a} \pm 0.02$	$7.11^{b} \pm 0.03$	81.45^{**}
	Nuggets	$6.92^{a} \pm 0.03$	$6.91^{a} \pm 0.03$	$7.28^{b} \pm 0.02$	17.56^{**}
	t - value	5.70^{**}	6.81^{**}	6.24^{**}	-

No. of samples – 8, means bearing different superscripts within columns (a, b, c) differ significantly.

*** = significant (P<0.05), ** = highly significant (P<0.01),NS = Non – significant (P>0.05),**

CHAPTER - V

DISCUSSION

A study was conducted to ascertain the various carcass characteristics, physico – chemical and organoleptic qualities, amino acid and fatty acid profiles, mineral content, value added product quality and histological parameters of meat from emu of two different age groups (15 and 18 months old).

A total of sixteen emus were subjected to this study and were divided into 15 and 18 months age groups. Each group consisted of 8 birds. The data on various carcass characteristics, physico-chemical properties, nutritional quality, amino acid profile, fatty acid profile, mineral content, organoleptic and microbiological qualities of emus of the two groups were collected and assessed.

Histological sections of emu meat samples were compared with that of beef and chicken. Comparative study of value added products prepared from emu meat, beef and chicken meat for physico-chemical properties and sensory evaluation were carried out and discussed.

5.1 Carcass characteristics

5.1.1 Carcass characteristics

A highly significant ($P<0.01$) difference in live weight, carcass weight, chilled carcass weight, dressing percentage, cooking loss (%) and meat: bone ratio, significant difference ($P<0.05$) in chiller shrinkage (%) and non – significant difference ($P>0.05$) in drip loss (%) was observed between 15 and 18 month emu birds.

The live weights recorded in emus of 15 months age group and 18 months age group were lower (27.85 kg and 30.62) compared to the live weights recorded at 14

months age group (40 kg) by Mannion *et al*., 1995, 40.6 kg at 17.5 months by Frapple (1992) and (35.1 kg) by Daniel, (1995). Significant and progressive increase in live weight and carcass weight was observed with advancement of age in the present study.

Carcass weights recorded in the 15 month age group (18.12 kg) in this study were much lower than that recorded in 13 month emu birds by Sales *et al*., (1999).The percent chiller shrinkage was between 5.86 to 8.14 per cent in 18 and 15 months emus respectively.

Dressing percentages of emus of 15 and 18 months were 65.06 and 67.95 respectively and were similar to that recorded by Daniel, (1995). Significant increase in dressing percentage with increase in age was also observed. In contrary, decrease in dressing percentage with increase in age was reported by Morbidini *et al.,* (1987) in sheep and Cifuni *et al*., (2000) in lambs whereas there was an increase in dressing percentage in buffaloes as was observed by Rao *et al*., (2009). The dressing percentage of emus as percent of live weights obtained in this study was almost similar to the values reported by Smetana, (1993) and Reddy *et al*., (2007).

The highly significant difference ($P<0.01$) in meat-bone ratio might be attributed to the increased fat deposition in older age groups as inferred by Cifuni *et al*., (2000) in lambs.

The findings of non significant difference in cooking loss between age groups in this study concurred with the results of Sales, (1994) in ostriches, Gullet *et al*., (1996) in beef and Hoffman and Fisher, (2001) in ostriches. Literature on emus were scanty.

5.1.2 Carcass measurement

There was a gradual and highly significant difference (P<0.01) in the length of the carcass (cm), neck (cm), shank (cm), trachea (cm), oesophagus (cm), intestine (cm), chest girth (cm), gigot length (cm) and gigot width (cm) between emus of 15 and 18 months age groups. The measurements of neck, shank, chest girth, gigot length and gigot width reflected on the carcass weights and dressing yields of emu carcass.

An increase in neck length contributed to increase in carcass weight and dressing percentage. Chest girth measurements reflected on the live weight of the birds, which are very much helpful in selection of the birds for slaughter. Ogah, (2011) inferred that chest circumference had the highest predictive power in live weight estimate. The observation made in this study was in agreement with this statement. Carcass measurements were shown to have higher correlation between live weight and carcass lean content in poultry (Bochno *et al.,* 1997, 1999 and Michalik *et al.*, (2002). Similar observations in terms of increase in carcass weight reflected by the Gigot length and Gigot width observed in this study was in agreement with the findings of Anous and Mourad, (2001) in Alpine kids (goat) .

5.1.3 Weights and Yields of edible offals

The weights and yields of heart and liver of emus of both the age groups observed in this study were closer to the values recorded by Sales *et al*., (1999) but were slightly lower than the values reported by Daniel, (1995). There was highly significant (P<0.01) and a linear increase in the weights of edible offals observed as age advanced. The yields of offals (per cent) such as heart, liver and gizzard did not show significant increase with age.

5.1.4 Weights and Yields of inedible offals

It was observed that the weights of all inedible offals of emus of both the age groups increased significantly ($P<0.01$) as age advanced. The significant increase ($P<0.01$) in weights of head and skin recorded as the age increased was in agreement with the results obtained by Salem *et al*., (1983) and Rao *et al.,* (2009) in buffaloes. However, the yields of offals such as skin, head and intestines did not differ significantly ($P>0.05$) with increase in age.

5.1.5 Weights and Yields of cut up parts

Specific procedures for carcass fabrication of emus have not yet been evolved except that followed by the Australian Quarantine Inspection service guidelines, (AQIS, 1993). Hence fabrication procedure that would suit the Indian emu market was newly experimented. Of the seven wholesale cuts (neck, rib, breast, drumstick, thigh, loin and rump) obtained, drumstick and thigh were observed to be the most lean portions.

Drumstick was the heaviest (4.41 kg) of all the emu cuts. This finding was in congruence with the observation made by Frapple, (1994). A significant effect of age was observed for limb and thigh yields with more favourable results produced by younger animals observed in this study was similar to that observed by Girolami *et al.,* (2003) in ostriches.

A highly significant increase in the weights and yields of cut up parts such as neck, breast and rib and loin were observed with increase in age, whereas a highly significant decrease in the weights of cut up parts such as drumstick, thigh and rump was observed with increase in age. These results are concurrent with that of results obtained by Cifuni *et al*., (2000) in lambs. In this study the decrease in weights and

yields of these portions may be attributed to the increase in deposition of fat in the birds of this age group (18 months).

5.2 Physico chemical parameters

5.2.1 pH

The pH of emu meat was observed to have a highly significant difference ($P<0.01$) between different muscle portions (drumstick, thigh and breast). In contrary, Berge *et al*., (1997) did not observe any significant difference in pH between different muscles of emu. There was no consistent effect of age on pH obtained and no significant difference was observed between the two age groups (15 and 18 months). The mean pH values obtained in both the age groups were similar to that obtained by Berge *et al*., (1997) in emus and were much lower than values obtained by Morris *et al*., (1995) and Sales and Mellet (1996) in ostriches. The pH of drumstick portion was observed to be higher than the other portions.

The progressive decrease in pH values during the storage periods indicated a normal trend. Similar decrease in pH on storage was also observed by Kandasami (1983) in cara beef; Rathina raj *et al.,* (2000) in chevon; and Rao *et al*., (2009) in buffaloes. The results obtained in the study were contradictory to the study made by Reddy *et al*., (2007) in pH of frozen emu meat.

5.2.2 Water holding capacity

There was a highly significant difference in water holding capacity of emu meat at different storage periods and between the two age groups. The water holding capacity decreased as age advanced and with increase in storage periods. Also there was a highly significant difference ($P<0.01$) noticed in the water holding capacity

between the muscle portions. The difference in water holding capacity between muscle portions of emus were similar to those observed by Ning Qiu, (1998).

The breast muscle portion was observed to have highest water holding capacity followed by thigh and drumstick. These findings were in accordance with that observed in between different emu muscle portions by Ning Qiu, (1998).

5.2.3 Extract release volume

The extract release volume is one of the methods of detecting freshness of meat. The extract release volume obtained for emu meat on the 0 day and an increase in volume at different storage periods was similar to that obtained by Reddy *et al*., (2007). There was no significant difference ($P>0.05$) in the extract release volume obtained from emu meat of the two age groups (15 months and 18 months old).

5.2.4 R – Value

The measurement of R – value is used to assess the development / status of rigor mortis in post- mortem period.

It was observed that the mean R – values at different storage periods (0, 1st, 2nd and 7th day) showed a gradual increase in different age groups upto 2nd day and a slight decrease at 7th day of storage. The R – value obtained in this study at 2nd day (1.25 - 1.29) in all age groups indicates the onset of rigor mortis during this period of chiller storage.

An increasing trend in R – value noticed up to 48h period (1.06 - 1.25 in 15 months age group and 1.14 - 1.29 in 18 month age groups) indicated the advancing of rigor mortis and there after a slight decrease in the R – value. Similar changes were

also observed by Sams and Mills (1993), Soares and Areas (1995) and Rao *et al.,* (2009) in other species.

5.2.5 Fibre diameter (µm)

There was highly significant difference in fiber diameter of emu meat between age groups and storage periods for both age groups. The observations made in this study are in congruent with the findings of Tuma *et al*., (1962), Romans *et al*., (1965) and Kastner and Henrickson, (1969). The gradual decrease in fiber diameter with increase in storage periods could be attributed to the fact of ageing which reflects in tenderness of meat. Similar results were reported by Rao *et al*., (2009).

5.2.6 Sarcomere length (µm)

There was highly significant difference in sarcomere length (µm) of emu meat between age groups and storage periods for both age groups. The values of sarcomere length (2.23 µm - 3.57 µm) obtained in this study were within the range (1.4 µm -3.6 µm) of values observed by Dingle (1997) in emu meat.

Significant difference ($P<0.05$) between age groups was observed in the current study. The increase in sarcomere length with increase in storage period is attributed to the effect of ageing. The decrease in sarcomere length with advancement of age in this study was complemented by Ffoulkes, (1992).

5.2.7 Myofibrillar fragmentation index (MFI)

Myofibrillar fragmentation index (MFI) is an accurate index of tenderness and is an useful indicator of the extent of proteolysis. There was a highly significant difference in MFI of emu meat between age groups and between storage periods for both age groups. Significant differences in MFI between age groups were also observed by Kandeepan *et al*., (2009) in buffalo meat. The increase in myofibrillar

fragmentation with storage period is a reflection of tenderization that is associated with post mortem ageing (Moller *et al.*, 1973; Olson *et al*, 1976).

5.2.8 Shear force value (kg/cm^2)

There was a highly significant difference in shear force values of emu meat of different age groups which was in congruence with the results obtained by Kandeepan *et al*., (2009) and Rao *et al*., (2009) in buffaloes. In contrary, no significant difference was observed in the shear force values between age groups of ostriches by Girolami *et al.,* (2003) and in cross bred steers by Gullett *et al*., (1996).

Shear force values of younger groups were lower relating to increased tenderness along with decreased fibre diameter as inferred by Locker, (1960); Berry *et al*., (1974) and Hearne *et al.,* (1978). A wide variation in the Warner Bratzler shear force values was found between muscles in ostriches by Sales (1996) and Girolami *et al*., (2003) and in emus by Thompson *et al*., (1995) and Ning Qiu, (1998).

Among the wholesale cuts drumstick showed the highest shear force value. These findings were similar to the results obtained by Ning Qiu, (1998). The shear force values obtained in this study were lower than that obtained by Reddy *et al*., (2007).

5.2.9 Collagen content (mg/g)

A highly significant difference in the collagen content of emu meat between the two age groups was noticed. Similar age related increase in collagen content was reported in bovine muscles by Bosselmann, *et al*., (1995) , Murthy and Devadasn, (2003) and Kandeepan *et al*., (2009) in Buffalo meat.

A highly significant difference was observed in collagen content between different muscle regions in this study. This finding is in accordance with that obtained by Ning Qiu, (1998) in emus. The finding that the drumstick region had the highest

collagen content (8.23mg/g) was also in agreement with that reported by NIng Qiu, (1998).

5.2.10 Texture profile analysis

All the texture profile variables revealed a highly significant difference between the two age groups as well as between the different muscle reigons. The increase in hardness values of the older age groups and the drumstick region was similar and was reflected in shear force values as well. The highly significant increase in the gumminess and chewiness values of the older groups and drumstick region reflected the decreased tenderness.

The parameter hardness is indicative of variation in tenderness of muscles as inferred by Caine *et al.,* (2003). The thigh region exhibited intermediary results in all the parameters of texture profile while the breast region showed the least values. Relationship between the instrumental measurements and sensory perception would predict consumer responses on the eating quality of meat (Szczesniak, 2002).

5.2.11 Thiobarbituric acid (TBA) number

There was significant difference ($P<0.05$) in the thiobarbituric acid number of emu meat between the two age groups and there was a gradual and highly significant increase in the thiobarbituric acid number of emu meat for both the age groups as storage increased.

This finding was in agreement with that found by Arif *et al.,* (1993) in stored chicken meat , Vijayakumar and Biswas, (2006) in refrigerated duck cutlet and Prabhakara Reddy *et al*., (2007) in TBA values of frozen emu meat. However, the observations obtained by Cifuni *et al*., (2000) in lambs were contrary to the above reports.

5.2.12 Tyrosine value

There was no significant difference (P>0.05) in the tyrosine value of emu meat between the two age groups but there was a gradual and highly significant increase in the tyrosine values of emu meat for different storage periods in both the age groups., Rajkumar *et al*., (2007) and Manimaran, (2007) also reported progressive increase in tyrosine value of meat and meat products during refrigerated storage.

5.2.13 Myoglobin content

There was a highly significant difference observed in the myoglobin content of emu meat of both the age groups as well as a highly significant differnce in myoglobin content was noticed in the different muscle regions of emu. The increase in the pigment content with age is consistent with the trend reported by Touraille *et al*., (1981a) in the chicken.

The wide variation in the myoglobin content of different emu muscles were in accordance with those observed by Sales, (2007) in emus and Balog and Almeida, (2007) in ostriches. Berge *et al*., (1997) also reported that meat pigment content in emu varied between different muscles and increased due to age.

The myoglobin content was highest in the drumstick muscle (1.23 -1.35) and least in breast regions. Similar results were obtained by Ning Qiu, (1998). The increase in redness in emu muscles with age is attributed to this pigment and similar finding was reported in ostrich muscles by Hoffman and Fisher, (2001) and Sales, (1996).

5.2.14 Spectrophotometric assay of meat colour

The colour of meat is an important attribute for the consumer and it has a decisive influence on the consumer. Highly significant differences in the Lightness (L^*) values between the two age groups and between the different muscle regions

were observed in this study. Richardson and Mead, (1999) mentioned that muscle pH and meat colour were correlated, and higher muscle pH was associated with darker meat. Likewise the values obtained for colour and pH in this study also revealed similar findings as evinced by the higher pH (5.65 – 5.66) and an intense redness (a*) noticed in drumstick region in both age groups.

The older birds (18 months) had significantly lower reflectance (L*) values ($P<0.01$) compared with the 15 month age groups indicating that emu muscles become darker and redder with increase in age, mainly due to increased concentration of myoglobin content. Similar results were obtained by Hoffman and Fisher, (2001) in ostriches and Boni *et al*., (2010) in japanese quails. However, the result obtained in this study was in contrary to those obtained by Dingle, (1995).

There was a highly significant difference in the spectrophotometric assay of meat colour values between the different muscle regions of emu as revealed in this study. This finding was similar to that observed by Mann *et al*., (1995) wherein there were small, but significant differences in the subjective evaluation of muscle colour in emus. In contrary, Ning Qiu, (1998) observed that there was no significant difference observed in hue, chroma and lightness values in raw emu cuts.

5.3 Nutritional Quality

5.3.1 Proximate composition and cholesterol content of emu meat

Nutritional information is heavily relied on by the consumers. Since emu meat is a newly introduced meat in the industry, imparting accurate knowledge of the composition of emu meat is important for health conscious consumers.

A highly significant difference ($P<0.01$) was observed in the fat, total ash values and cholesterol content and a significant difference ($P<0.05$) was observed in the moisture content of the meat from the two age groups. In contrary, Berge *et al*.,

(1997) reported that there was not much difference noticeable in the composition of meat between age groups of emu except the lipid content.

Sales, (2007) also observed that the moisture, protein and lipid content did not differ significantly except the pigment and collagen content of the meat from different ages of ostriches. The moisture, protein and ash contents observed in this study were comparable to those obtained by Sales (1996) in ostriches, Daniel, (1995), Berge *et al*., (1997), Sales and Horbanczuk, (1998), Pegg *et al*., (2006) and Reddy *et al.,* (2007) in emus. Higher protein and moisture from meat of younger age groups were also reported by Boni *et al*., (2010) in spent quails.

Lower lipid levels in younger groups was observed in this study. However, some researchers Hoffman and Fisher, (2001); Girolami *et al*., (2003); Sabbioni *et al*., (2003) studied lipid content in the carcasses of ostriches slaughtered at different ages and did not find any significant difference in lipid content.

However in quality of lipids the highly significant difference noted in the cholesterol content of the meat from the two age groups was not in agreement with Girolami *et al*., (2003). The cholesterol content (mg /100g) of emu meat of both the age groups observed in this study (24.42 - 26.13) were much lower than that reported by Frapple, (1994), Daniel, (1995) and Dingle, (1997) in emu meat. The low cholesterol content may also be due to the feed supplied to them.

5.3.2 Proximate composition and cholesterol content of emu meat, beef and chicken meat

A highly significant difference in the proximate composition was observed between emu, beef and chicken meat. Emu meat was observed to contain the highest

protein, lowest fat content when compared to the other red (beef) and white (chicken) meat. The observations were in agreement with those of Daniel, (1995).

With regard to cholesterol content the values reported by Daniel, (1995) in emus were much higher than that obtained in this study. The differences may be due to different analytical and extraction procedures

The moisture, protein and fat contents of beef and chicken observed in comparison with emu in this study were similar to those observed by Sales and Hayes (1996) in a comparison study with ostrich meat and Paleari *et al* ., (1998) in a study of ostrich meat compared with bovine and turkey.

Emu cutlets had higher protein in comparison with beef and chicken. Similar observations were made by Karthick, (2012). Of the meat from emu, bison, cattle, turkey and elk, reported in the University of Wisconsin – Madison study (2000), emu meat was found to be the richest source of protein as observed in this study.

5.3.3 Mineral content

It was observed that the mineral contents between the muscle regions as well as between the age groups of emu birds differed significantly. The drumstick cut exhibited more content of all the minerals compared to the thigh and breast cuts. This finding was in congruence with the observations made by Ning Qiu, (1998) in different emu muscles. Sodium (in ppm) was found to be the predominant mineral (43.11- 46.43) followed by magnesium (21.68 – 24.50), calcium (4.42 -5.49) and iron (4.99 -5.20).

The minerals magnesium, calcium, sodium and zinc were found to be more in younger animals than the older groups. Also these minerals were found to be more in the drumstick cut. The probable reason may be due to increased activity in the

younger age groups in these cuts. Similar results were obtained in emus by Daniel, (1995). The other minerals were significantly higher in the older age groups.

5.3.4 Fatty acid profile

The consumers of today are searching for food items with higher levels of health enhancing fatty acids due to the positive association between animal fat and certain diseases (Simpoulos, 1991; Fernades and Venkataraman, 1993). Hence an understanding of the lipid characteristics of emu meat is important.

The fatty acid profile revealed a highly significant difference between the two age groups. The saturated fatty acids were significantly higher in the older age groups. The monounsaturated and polyunsaturated fatty acids were more in the younger age groups. The ratio of polyunsaturated fatty acids to saturated fatty acids in emu meat was 0.75 and 0.51 in 15 and 18 months age groups respectively. The ratio obtained by Wang *et al*., (2000) for emu meat was similar to that of the 15 month age group.

Oleic acid (C18:1) was the predominant monounsaturated fatty acid and the polyunsaturated fatty acids such as the linoleic (C18:2) and linolenic (C18:3) were all significantly higher in the younger groups. The mean linoleic (n-6): linolenic(n-3) ratio was found to be influenced by age at slaughter, since this ratio was less in younger groups, these birds seem to produce meat with a n-6:n-3 ratio more compatible to those consumers who are health conscious. Similar observations were made by Girolami *et al*., (2003) in ostriches.

The major monounsaturated fatty acid, the oleic acid (C18:1) comprised over 50 percent of the total fatty acids. It was reported that oleic acid can enhance penetration of biologically active compounds that have been proven to be beneficial to

the skin, thus has been widely used as a carrier base in cosmetic industry (Frapple, 1992).

Saturated fatty acids such as the myristic (C14:0), palmitic (C16:0) and the stearic (C16:0), considered to be hyper cholesterolemic were profoundly increased in the older age groups (18 months) which is a serious issue to be taken into consideration. The results of variation in the saturated and unsaturated fatty acids between the younger and older groups obtained in this study were similar to those obtained by Sales, (2007) in emus, Hoffman and Fisher, (2001) and Girolami *et al*., (2003) in ostriches.

5.3.5 Amino acid profile

Emu meat as evidenced from the proximate composition of the meat is an excellent and valuable source of protein with very good amino acid profile. It was observed in this study that a highly significant difference existed in the agrinine, aspartic, glutamic, histidine, isoleucine, leucine, lysine, methionine, phenylalanine and threonine contents of emu meat from both the age groups.

However, no significant difference was observed in the contents of alanine, glycine, serine, tyrosine and valine. The content of essential amino acids were more in the younger age groups compared to the older groups which are of primary concern to the nutritionists.

The predominant amino acids were aspartic, glutamic, leucine and lysine. Except for glutamine and serine all the other amino acids were lower in the older groups. The amino acid content (g/100g) observed in this study were close to those obtained by Sales and Hayes, (1996) in ostriches.

5.4 Organoleptic characteristics

The emu meat from the younger age groups exhibited higher scores for all the sensory parameters. The increased myoglobin content in the older age groups could be the reason for the lower scores for the appearance and flavor attributes of this age group. However, Girolami *et al.*, (2003), did not find any effect of age at slaughter on the intensity of meat flavor in ostriches.

Decreased scores for tenderness and juiciness given to the older age groups by the sensory panelists could be interpreted as a reflection of high shear force values and increased collagen with increase in age. The decrease in tenderness with age is in agreement with the observations made in chickens by Touraille *et al*., (1981) and Berge *et al*., (1997) in emus. The decrease in tenderness score may be attributed to decreased activation of the μ calpain in older ones (Morgan *et al*., 1993).

5.5 Microbiological quality

Microbiological quality revealed no significant difference ($P>0.05$) between the two age groups. Gill *et al*., (2000) observed greater number of total aerobes indicating processing contamination in ostriches.

5.6 Value added products

Processing emu meat into value added products would contribute to sustained demand for the meat and its efficient marketing to earn reasonable returns by the Producers. It provides taste, convenience to the meat consuming population with exceptional level of satiety. Also value added products would be a clear indication for raising demand for emu meat and its products by creating awareness about the health benefits and advantages of the emu meat and its products.

5.6.1 Physico chemical characteristics of emu meat, beef and chicken meat products

The results of the study revealed a highly significant difference ($P<0.01$) in the emulsion stability between the products prepared from emu meat, beef and chicken meat. However no significant difference ($P>0.05$) was observed in the emulsion stability between the products. But there was a highly significant difference ($P<0.01$) noticed in the yield of the products (sausages and nuggets) and also between the products prepared from different emu meat, beef and chicken meat.

The difference in the yield between the products (sausages and nuggets) may be due to the difference in the cooking methods and cooking temperatures of sausages (cooked in hot water) and nuggets (cooked in steam). Sausages and nuggets from emu meat exhibited more stability and product yield values than beef and lower values than chicken. Increased product yield in emu meat products were also observed by Shao *et al*., (1999). The decreased yield in beef products may be due to increased fat level which in turn increased the evaporative loss during cooking as indicated by Trout *et al*., (1992).

5.7 Sensory evaluation of emu meat, beef and chicken meat products

Emu meat products received more taste panel scores compared to beef in appearance, tenderness and juiciness. The reduced flavour scores of the emu meat products might be attributed to the increased “gamey” flavour and also due to the after effects of the product remaining in the palate observed by the panel. Beef products were preferred for their flavour which could have been due to enhancement by its intramuscular fat content. Incorporation of increased spice mix and suitable binders

that would mask the “gamey” flavour could be tried to make the emu products more palatable.

5.8 Histology of Emu meat, Beef and Chicken meat

Hematoxylin and Eosin stained muscle tissue sections of emu, beef and chicken were studied. The study revealed that the fibre diameters of emu tissues (12 – 14µm) were similar to that of chicken (11 - 13µm) than beef (23 - 30µm). The fibre diameters of emu tissues observed histologically were much lower than the histological observation of ostrich fibre diameters (51 - 57µm) as reported by Sales, (1996).

5.9 Conclusion

This study on various carcass characteristics, physico – chemical qualities, meat quality traits, microbial quality and histological studies of emu birds of two different age groups (15 and 18 months) have brought out the salient findings. These salient findings have been abstracted here under:

S. No.	Parameters	15 months	18 months
	Carcass characteristics		
1.	Live weight (Kg)	27.85	30.62
2.	Carcass weight (Kg)	18.12	20.81
3.	Chilled Carcass weight (kg)	16.65	19.59
4.	Chiller Shrinkage (%)	8.14	5.86
5.	Dressing per cent (%)	65.06	67.95
6.	Meat : Bone ratio	3.02	2.65
7.	Drip loss (%)	1.71	2.32
8.	Cooking loss (%)	30.74	31.19
	Carcass measurements (cm)		
9.	Carcass length	46.43	52.17
10.	Neck	56.97	62.35
11.	Shank	53.26	56.57

12.	Trachea	67.95	75.78
13.	Oesophagus	71.33	80.34
14.	Intestine	437.45	452.12
15.	Chest girth	67.34	72.06
16.	Gigot length	43.08	53.20
17.	Gigot width	27.87	33.86
	Yield of edible offals (%)		
18.	Heart	1.35	1.39
19.	Liver	1.43	1.45
20.	Kidney	0.65	0.74
21.	Gizzard	1.18	1.22
	Yield of inedible offals (%)		
22.	Blood	6.69	8.24
23.	Feather	2.43	2.76
24.	Skin	15.61	16.12
25.	Shank	5.92	6.99
26.	Head	1.73	1.79
27.	Lungs	1.66	1.74
28.	Intestines	3.31	3.55
29.	Proventriculus	0.39	0.74
30.	Spleen	0.17	0.37
31.	Trachea	0.56	0.62
32.	Oesophagus	0.44	0.52
33.	Wings	0.26	0.33
	Yield of cut up parts (%)		
34.	Neck	1.67	2.07
35.	Rib	1.52	1.57
36.	Breast	0.42	0.55
37.	Drumstick	15.61	13.78
38.	Thigh	4.31	4.04
39.	Loin	3.07	2.42
40.	Rump	3.77	2.85
41.	Fat	12.71	15.30
42.	Bone	12.26	13.92
	Physico – chemical properties		
43.	pH	5.66	5.65
44.	WHC (cm^2)	1.41	1.33
45.	R – value	1.06	1.09

46.	ERV (ml)	20.64	20.59
47.	TBA No.(mg . malonal / Kg)	0.56	0.67
48.	TV (mg/100g)	1.10	1.09
49.	Fibre diameter (μm)	14.35	17.27
50.	Sarcomere length (μm)	2.92	2.23
51.	MFI	720.75	737.38
52.	Myoglobin content	1.23	1.35
53.	SFV (kg/cm^2)	3.11	3.27
54.	Collagen (mg/g)	7.27	8.23
	Spectrophotometric assay of meat colour		
55.	Lightness (L)	31.27	28.36
56.	Redness (a*)	11.12	11.76
57.	Yellowness (b*)	5.78	6.84
58.	Hue	0.59	0.45
59.	Chroma	15.91	16.90
	Texture profile analysis		
60.	Hardness (kgf)	53.62	55.14
61.	Springiness (mm)	0.64	0.94
62.	Cohesiveness (ratio)	0.33	0.43
63.	Gumminess (N)	17.95	24.12
64.	Chewiness (kgf/mm)	11.62	22.65
	Proximate composition (%)		
65.	Moisture	72.23	71.72
66.	Protein	24.07	23.81
67.	Fat	2.62	3.26
68.	Total Ash	1.08	1.21
	Cholesterol content (mg/100g)		
69.	Cholesterol	24.42	26.13
	Amino acid profile (g / 100g)		
70.	Alanine	6.08	6.04
71.	Arginine*	6.45	6.27
72.	Aspartic	9.44	9.29
73.	Glycine	5.02	5.06
74.	Glutamic	15.32	16.12
75.	Histidine*	4.61	3.46
76.	Isoleucine*	5.12	5.05
77.	Leucine*	8.44	8.37
78.	Lysine*	9.27	9.19

79.	Methionine*	2.94	2.86
80.	Phenylalanine*	4.53	4.49
81.	Serine	4.45	4.47
82.	Threonine*	4.52	4.34
83.	Tyrosine*	4.04	4.03
84.	Valine*	5.03	5.02
	Fatty acid profile (%)		
85.	Myristic Acid (C14:0)	0.71	0.98
86.	Palmitic Acid (C16:0)	19.05	22.03
87.	Stearic Acid (C18:0)	10.13	14.34
88.	Arachidic Acid (C20:0)	0.14	0.21
89.	Palmitoleic Acid (C16:1)	4.03	3.53
90.	Oleic Acid (C18:1) *	33.97	30.36
91.	Linoleic Acid (C18:2) **	17.45	15.94
92.	Linolenic Acid (C18:3)**	4.32	2.97
93.	Docosohexanoic Acid (C22:6) *	0.73	0.46
	Mineral content (ppm)		
94.	Aluminium	0.50	0.53
95.	Boron	0.17	0.18
96.	Calcium	5.49	4.42
97.	Cobolt	0.001	0.002
98.	Chromium	0.10	0.11
99.	Copper	0.16	0.17
100.	Iron	4.99	5.20
101.	Magnesium	21.68	24.50
102.	Manganese	0.04	0.08
103.	Sodium	46.43	62.14
104.	Zinc	3.51	3.92
	Organoleptic quality		
105.	Appearance	7.43	6.19
106.	Flavour	7.33	6.39
107.	Tenderness	8.11	7.56
108.	Juiciness	8.48	7.28
109.	Overall palatability	7.84	6.81
	Microbiological quality (cfu/g)		
110.	Total Plate Count	2.41	2.56
111.	Salmonella	ND	ND
112.	Coliforms	ND	ND

Based on the above observation, it could be concluded that the emu birds of 15 months age group are having better carcass characteristics, superior meat quality traits, extremely beneficial nutritive value, with desirable organoleptic characteristics and appreciable meat yield than the 18 month age groups.

Hence, it is advocated that the production of younger animals (15 months age) and the selection of particular muscles will satisfy the demand of consumers for meat with adequate nutritional and sensory properties. In addition, a short production cycle with lower ages at slaughter and higher production efficiency may contribute in reducing production costs and retail prices.

CHAPTER VI

SUMMARY

A study on various carcass characteristics, meat quality traits and value added products of emu of two different age groups (15 and 18 months) was carried out in the Department of Meat Science and Technology, Madras Veterinary College, Chennai –7.

Emu, a native of Australia, has set its foot prints in Indian poultry industry remarkably with an excellent technical and economic feasibility. Emu meat is developing interest in nutritionists owing to its higher protein content, lower fat and calorific value than beef, pork and chicken. Emu meat is an excellent altenative to red meat for the health conscious consumers. The simple nutritional and managemental requirement of the bird and its innate adaptability have attracted the growth of emu industry in India. The current study has undertaken the parameters that would reflect on the economic feasibility of the bird in Indian meat scenario.

The study on the carcass characteristics include live weight (kg), carcass weight (kg), chilled carcass weight (kg), chiller shrinkage (%), dressing per cent, meat: bone ratio, drip loss (%) and cooking loss (%) and carcass measurements (cm) like length of the carcass, neck, shank, trachea, oesophagus, intestine, chest girth, gigot length and gigot width. The data on yield characteristics include weights and yields of edible and inedible offals and cut up parts.

The meat quality traits studied were physico – chemical parameters like pH, water holding capacity, R – value, extract release volume, thiobarbituric acid number, tyrosine value, fibre diameter, sarcomere length, myofibrillar fragmentation index, myoglobin percent, shear force value and collagen content, spectrophotometric assay of meat colour, texture profile, proximate composition and cholesterol content, amino

acid profile, fatty acid profile, mineral content, organoleptic quality and microbiological quality. Histological study by Hematoxilyn and Eosin staining was carried out to compare the muscle fibre diameters of emu, beef and chicken meat. Value added products were prepared and compared with beef and chicken products.

Significant and progressive increase in live weight and carcass weight was observed with advancement of age in this study. Despite an increase in the dressing yields with age, the meat: bone ratio was found to influence the age of selection.

The carcass measurements showed a linear increase with age. The body measurements had a linear relation with the carcass weights and dressing percentage. An increase in neck length contributed to increased carcass weights and dressing percentage.

There was a significant and linear increase in the weights of edible and inedible offals as age advanced with less or no significant change in their yields. A highly significant increase in weights and yields of cut up parts with age was evinced except for the major meat cuts like drumstick and thigh. Drumstick and thigh were the major meat cuts and breast was smallest meat cut. The yield of drumstick and thigh decreased with age which might be due to increased fat deposition as age advanced.

Results of the physico – chemical parameters revealed a gradual decrease in pH from 0 day (5.58 - 5.66) to 1st day (5.43 – 5.46) of storage period and a slight increase in pH at 7th day (5.53 – 5.52) of storage in different age groups. The progressive fall in pH during the periods of storage in chiller and freezer is normal.

The water holding capacity decreased as age advanced and with increase in storage periods. Also there was a highly significant difference noticed in the water holding capacity between the muscle regions. The breast had highest water holding capacity of the three muscle cuts and the drumstick the lowest.

The mean of R – values at 0, 1st, 2^{nd} and 7^{th} days indicated a gradual increase upto 2^{nd} day and a slight decrease at 7^{th} day of storage in both the age groups. The R-value obtained in this study at 1^{st} day ranged from 1.06 -1.24 in both the age groups indicating the onset of rigor mortis at chiller storage during this period.

The extract release volume of both the age groups increased gradually and consistently throughout the storage period. The thiobarbituric acid number and tyrosine values increased significantly at different storage periods for both the age groups and there was no significant difference in the tyrosine values between the age groups.

The observations revealed significant increase in fibre diameter as age advanced (14.35µm – 17.27 µm). The fibre diameter decreased gradually during the storage periods resulting in increased tenderness.

The observations obtained for sarcomere length in this study revealed significant decrease in sarcomere length as age advanced (2.92 µm – 2.23 µm). The sarcomere length increased gradually with storage period also indicating increase in tenderness.

The Myofibrillar fragmentation index results revealed an increase with storage period which is a reflection of tenderization that is associated with post mortem ageing. There was significant difference noticed in the Myofibrillar fragmentation index between the age groups.

The results of this study revealed that the myoglobin content increased significantly with age. The drumstick cuts had the highest and the breast cuts had the lowest myoglobin percent.

Warner Bratzler shear force value (kg/cm^2), an objective measure of tenderness in this study revealed that the shear force value increased significantly as

the age advanced. The drumstick cuts had the highest and the breast cuts had the lowest shear force value.

Collagen content, a direct indicator of tenderness increased significantly with age. The collagen content was more in the drumstick than the thigh and breast cuts.

The instrumental colour values of the two age groups of the three muscle regions revealed that the older birds (18 months) had highly significant and lower reflectance (L*) values ($P<0.01$) compared with the 15 month birds which indicated that emu muscles become darker and redder with an increase in age, mainly due to increased concentration of myoglobin. Drumstick cuts revealed to have minimal lightness (L*) and intense redness (a*), thigh cuts were found to be intermediary and breast cuts had the highest lightness (L*) and lowest redness (a*). Hue values were more in drumstick and the breast showed more chroma values.

The texture profile results revealed that the younger age groups had decreased hardness, springiness, cohesiveness, gumminess and chewiness values than the older birds. The texture parameters also indicated drumstick to be the tougher cut than thigh and breast. Since there is only minimal meat yield from the breast cuts, the thigh cuts could be considered as prime choice for eating attributes.

The nutritive value of meat is mostly claimed by health conscious consumers. There was increased percentage of moisture and protein observed in the younger age groups. The fat and cholesterol percentages were very less in the younger group which is of concern to nutritionists. The comparative analysis of the proximate composition in emu, beef and chicken meat revealed that emu meat had the highest protein and lowest fat and cholesterol percentages.

The amino acid profile observed in this study revealed that a highly significant difference existed in the agrinine, aspartic, glutamic, histidine, isoleucine, leucine,

lysine, methionine, phenylalanine and threonine contents of emu meat from both the age groups. The content of essential amino acids were more in the younger age groups compared to the older groups which are of primary concern to the nutritionists. The predominant amino acids were aspartic, glutamic, leucine and lysine. Except for glutamine and serine all the other amino acids were lower in the older groups.

The fatty acid profile revealed a highly significant difference between the two age groups. The saturated fatty acids were significantly higher in the older age groups. The monounsaturated and polyunsaturated fatty acids were more in the younger age groups. Oleic acid (C18:1) was the predominant monounsaturated fatty acid and the polyunsaturated fatty acids such as the linoleic (C18:2) and linolenic (C18:3) were all significantly higher in the younger groups. Saturated fatty acids such as the myristic (C14:0), palmitic (C16:0) and the stearic (C16:0), considered to be hyper cholesterolemic were profoundly increased in the older age groups (18 months).

It was observed that the mineral contents between the muscle regions as well as between the age groups of emu birds were differing significantly. The drumstick cuts exhibited more content of all the minerals compared to the thigh and breast cuts. The minerals magnesium, calcium, sodium and zinc were found to be more in younger animals than the older groups. Also these minerals were found to be more in the drumstick cuts

The emu meat from the younger age groups exhibited higher scores for all the sensory parameters. Decreased scores for tenderness and juiciness given to the older age groups by the sensory panelists could be interpreted as a reflection of high shear force values and increased collagen with increase in age.

Microbial quality revealed no significant difference ($P>0.05$) between the two age groups.

Value added products would be a clear indication for raising demand for emu meat and its products by creating awareness about the health benefits and advantages of the emu meat and its products. The hunter scores for lightness revealed chicken product as the highest scorer for lightness as chicken was obviously white meat. Between the products of emu and beef, emu sausages and nuggets exhibited less intense colour.

The texture profile analysis of the products revealed a highly significant difference ($P<0.01$) between the products as well as between the different species. Emu products exhibited lesser values of all the textural attributes than beef but values were more than chicken. Emu sausages and nuggets were intermediary between beef and chicken. The values for gumminess and chewiness were much less than beef.

The results of the study revealed a highly significant difference ($P<0.01$) in the emulsion stability between the products prepared from emu, beef and chicken meat. There was a highly significant difference ($P<0.01$) noticed in the yield of the products (sausages and nuggets) and also between the products prepared from emu, beef and chicken. Emu sausages and nuggets exhibited more stability and product yield values than beef and lower values than chicken.

Emu products received more taste panel scores compared to beef in appearance, tenderness and juiciness. The reduced flavour scores of the emu products may be attributed to the increased “gamey” flavour.

Microbiological quality of the products prepared from emu, beef and chicken showed a significantly higher difference in the microbial counts at different storage periods. However, the counts were within the acceptable limits.

Hematoxylin and Eosin stained muscle tissue sections of emu, beef and chicken revealed that the fibre diameters of emu tissues (12 – 14µm) were similar to that of chicken (11 - 13µm) rather than beef (23 - 30µm).

The results of the study indicated that emu birds of 15 month age group can be selected for slaughter considering the various favourable characteristics like meat : bone ratio, high meat yield (drumstick and thigh cuts), reduced drip loss and cooking losses, and the meat quality traits like pH, water holding capacity, R – value, extract release volume, thiobarbituric acid number, tyrosine value, fibre diameter, sarcomere length, myofibrillar fragmentation index, myoglobin percent, shear force value and collagen content, instrumental colour, texture profile analysis, proximate composition and cholesterol content, amino acid profile, fatty acid profile, mineral content estimation. The organoleptic scores also were supportive to the 15 month age group. The comparison of value added products were also favourable to emu meat.

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