Animal Science Papers and Reports vol. 29 (2011) no. 1, 5-18
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The ostrich meat – an updated review. I. Physical characteristics of ostrich meat*

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(Received September 9, 2010; accepted January 10, 2011)

The presented Part I of the review provides current information about colour, flavour and aroma, tenderness, pH, water-holding capacity and drip loss, shelf-life and microbial load, cold shortening and cooking losses of ostrich meat which is darker and contains more redness compound compared to the beef or pork. On average, ostrich meat has been classified as intermediate with regular (<5.8) to high (>6.2) pH as measured 24 h post-slaughter, generally with a rapid decline of pH. Tenderness of ostrich meat depends on type of muscle from which it originates. Its water-holding capacity is lower compared to pork or chicken meat, but similar to veal and beef.
Cited are 60 references.

KEY WORDS: meat /ostrich / physical characteristics

Introduction

Over the last decade there is still observed a growing interest in ostrich farming and husbandry worldwide [Cooper *et al*. 2004, 2007, 2008, Horbańczuk *et al*. 2004ab, 2007]. One of the reasons of such interest is versatility of the use of ostriches which

*Realized within the project "BIOFOOD"- innovative, functional products of animal origin no.POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007-2013
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provide valuable products, especially meat as well as skin, feathers and eggs [Sales *et al*. 1999, Horbańczuk 2000, 2002, Horbańczuk *et al*. 1998, 2004, Cooper and Horbańczuk 2004, Kawka *et al*. 2007]. It should be noted that because of the dioxine problems in 1999 (Belgium), second outbreak of BSE (2000) in Europe and foot and mouth disease in 2001 in UK [Horbańczuk *et al*. 2008] the demand for ostrich meat has increased. The consumption of beef in Europe at that time declined and consumers started to look for alternative kinds of red meat from not traditional species like ostrich. Europe is currently the biggest world market for ostrich meat, importing it mainly from South Africa, Israel and even Australia [Horbańczuk *et al*. 2008].

Although research on ostrich meat was reviewed by Paleari *et al*. [1995], Sales and Oliver-Lyons [1996], Sales and Horbańczuk [1998], Cooper [1999], Cooper and Horbańczuk [2002] and Hoffman [2005], our knowledge about its quality is still limited. Facing the above, the aim of part I of this review is to provide information about physical properties of ostrich meat covering colour, flavour and aroma, tenderness, pH, water-holding capacity and drip loss, shelf-life and microbial load, cold shortening and cooking losses.

Colour

Colour is one of the most important attributes of the meat because it strongly affects consumers' choices and is mostly visible characteristics of it [Carpenter *et al*. 2001]. Despite being a poultry meat, ostrich meat has slightly dark red ranging to slightly cherry red colour, which is a bit lighter than that of beef. This can be explained by a high pigment content reported by Naude *et al*. [1979] as 22-30 μg Fe/g. Balog and Almeida Paz [2007] reported this value to vary between different ostrich muscles where *flex cruris lateralis, iliofibularis* and *iliotibialis cranialis* show most intensive colour. They also explained that meat colour is influenced by water-holding capacity. When the water holding capacity of meat is high then such parameter as absorption of radiation of this meat is high as well. In connection to this fact, reflection of this meat becomes lower and this causes its darker colour. Usually, in order to measure meat colour parameters the following indicators are used: L* – lightness, a* – redness (brownness), b* – yellowness, h* – hue and C* – chroma. [CIE colour space, 1976,

Table 1. Meat colour parameters of different poultry species

Reference	Species	L*	a*	b*	h*	C*
Fernández-López *et al*. [2008]	ostrich	38.4	15.5	8.4	40.0	15.8
Majewska *et al*. [2009]	ostrich	31.5-33.5	16.7-19.1	11.3-13.3		
Millar *et al*. [2000]	chicken	61.63	5.48	7.15	51.6	9.15
Millar *et al*. [2000]	goose	54.90	7.39	1.95	14.3	7.69
Millar *et al*. [2000]	turkey	59.21	6.39	5.72	41.8	8.64

L* – lightness, a* – redness, b* – yellowness, h* – hue, C* – chroma.

USA). Hoffman *et al*. [2008] summarized ranges of those parameters for ostrich meat. The L* value for 10 different muscles from three ostrich subspecies ranged from 27.4 to 34.4, the a* from 10.7 to 17.1 and b* from 6.0 to 9.3. Similar results were reported for ostrich meat by Fernández-López *et al*. [2008] for a* and b* values, but higher for L*. Also Majewska *et al.* [2009] investigated the ostrich meat colour parameters. Some of their results differ, however, from these cited above due to meat samples mincing. Comparing to other poultry species ostrich meat has lower L* and higher a*, b* and C* values (Tab. 1).

Among other factors, deboning, packaging and storage conditions greatly influence the colour of ostrich meat. Otremba *et al.* [1999] compared the effect of post-slaughter time on colour parameters of ostrich minced meat and steaks. Generally, the L* value combined for both types of meat increased from 29.68 to 32.87 during 28 days of storage in 0°C, which is higher than in beef or turkey meat. They also observed that b* value differed between two forms of samples preparation. This value changed from the point of time just before freezing to day 0 of display, however it did not change after this point till the day 28th. Increase in brownness occurred between day 14 and 28 in minced samples, while in steak samples between day 3 and 21. The general trend identified by Otremba *et al*. [1999] in the study in question was that initially dark purple-red colour has changed to reddish-brown during 28 days of refrigeration. Minced meat was more brown during that period (from 1 to 75%) than steak (up to 55%).

The influence of package method on the ostrich meat colour has been reviewed by Cooper and Horbańczuk [2002], however, since that publication some new trials were conducted with regard to this topic. In 2007 Gonzalez-Montalvo *et al.* [2007] reported the results of inoculation of ostrich steaks with two strains of pathogenic bacteria (*Listeria monocytogenes* and *Escherichia coli*). Steaks were then packaged in two different ways: with access of air and under vacuum and stored at 4 and 10°C, respectively. Generally, colour of the examined samples was influenced by water exclusion to a greater extend in vacuum-packaged samples. The temperature of storage affected only the air-packaged samples and especially those stored at 4°C. Unacceptable scores for colour were observed after day 6 in air-packaged, day 12 in vacuum-packaged at 10°C samples and after day 15 for vacuum-packaged samples stored at 4°C. Another investigation which tested the packaging method was done by Fernandez-Lopez *et al.* [2008]. The air-packaged, vacuum-packaged and packaged in modified atmosphere (MAP, with or without CO) samples were compared. The conclusions were that initial mean surface L* value of 38.4 was similar to reported by other authors [Navarro *et al*., 2000] and it increased during storage in all cases. However, of samples stored in MAP with CO the meat colour was lighter. On the other hand, the a* value fell down during storage in all cases, remaining, however, the highest in MAP and vacuum-packaged samples. Indicator b* responded in this study in the same way as a*. The final conclusion from the cited study by Fernandez-Lopez *et al* [2008] was that the best packaging option for maintaining the best ostrich meat colour would be MAP+CO while the worst the vacuum and MAP by itself.

Additionally, red colour is best kept in MAP+CO packaging for 18 days, while the same score for red colour remains in air-packaged samples only for 4 days. The addition of CO to MAP occurred to be an important factor due to its shelf life extending and red colour preserving properties.

The influence of cold- or hot-deboning on the meat colour was estimated by Botha *et al*. [2006] who reported that generally, cold-deboned muscles showed lower L* over 21 days of ageing compared to hot-deboned. L* increased during the time causing lighter colour in both cases. This process has been explained by Lawrie [1998] as a result of oxidation and denaturation of myoglobin. Moreover, as pH decreased, muscles became lighter, redder and more yellow (higher L*, a* and b*, respectively).

Flavour and aroma

Flavour and aroma are quite subjective characteristics of meat, usually evaluated by the sensory panels and related to many other traits measurable in more exact way (texture, temperature and pH). Usually panellists compare the taste of ostrich meat to that of beef [e.g. Harris 1994] and classify it as bland with preference for beef. Balog and Almeida Paz [2007] in their review, however, conclude that ostrich meat is attractive for the consumers due to its differences from beef, especially high ultimate pH and low intramuscular fat content. Flavour of different muscles is similar, but the differences between particular muscles in their taste are recognizable and have been described. Usually, internal parts like *iliofemoralis* or *obturatorius medialis* muscles have stronger taste compared to external parts muscles, for example g*astrocnemius pars interna* and *externa* which present mild flavour. Ostrich meat has a natural fishy aroma [Hoffman *et al*., 2006] what was confirmed by panellists.

Studies were conducted aiming at evaluating the effect of slaughter method, deboning or bird age on ostrich meat flavour, but no significant influence has been found of those factors [Hoffman *et al*. 2005, Botha *et al.* 2006]. However, other authors reported that type of package and storage time affect the meat sensory characteristics, specially the aroma. Gonzalez-Montalvo *et al.* [2007] found that gas-atmosphere packaging and temperature both influenced the hedonic score of panellists. A marked influence of storage temperature on sensory scores was observed in air-packaged ostrich steaks. In that study strong odour was influenced by exclusion of oxygen with higher scores for samples vacuum-packaged at 4°C and 10°C. Similar results were presented by Capita *et al.* [2006], where on day 9 the samples stored at 10°C and air-packaged at 4°C showed off-odours when opening the bag. None of the samples vacuum-packaged and stored at 4°C had any odour, they also showed lowest microbial counts - not higher than $7\log^{10}$ CFU/g (lactic acid bacteria) or higher than $5\log^{10}$ CFU/g (fluorescent *Pseudomonas*). Also Fernandez-Lopez *et al.* [2008] found that air-packaged ostrich meat samples had the highest score for odours (sour and putrafective). Vacuum- and MAP-packaged samples reacted similarly - no changes were observed during first 4 days of storage. In the study by Otremba *et al.* [1999]

frozen and vacuum-packaged ostrich meat was stored for 28 days to determine its refrigerated shelf life. Off-odour has changed during 28 days from none to small. The meat remained under microbial test, the results of which occurred unacceptable until day 21 from being frozen. Unacceptable aroma occurred after 14 days. It was concluded that frozen, vacuum-packaged and further kept frozen ostrich meat should be used within 10 days in order to avoid sensoric negative effects.

Tenderness

Risvik [1994] has described tenderness as one of the main meat quality attributes important for its acceptability and purchasing intention of consumers. In ostrich meat tenderness is an appreciated trait due to low levels of fat and collagen to protein ratio (0.9-1.5% and 0.44%, respectively), responsible for meat texture – ease of chewing and digestibility. Additional determining factor is arrangement of muscle fibres oriented transversally in ostrich muscles [Balog *et al.* 2006]. Shear values are higher when the fibres are oriented longitudinally (11.5 kg/g) compared to the transverse orientation (7.4 kg/g).

Sales and Oliver-Lyons [1996] classify ostrich muscles according to Warner-Bratzler shear force into three groups: most tender (e.g. *femorotibialis medius* and *iliofemoralis*), tender (*ambiens*) and least tender (*iliofibularis*). This classification is, however, subjective and affected by many variables including duration of cooking. Giorlami *et al.* [2003] similarly indicated that tenderness depends on muscle type.

Tenderness as a trait consists of such elements as ease of shearing or cutting during mastication [Cooper and Horbańczuk 2002]. Balog and Almeida Paz [2007] in their review mention that various results concerning the trait are hardly comparable due to variation in cooking methods, temperatures and tools used to obtain this measure. Mostly used method - Warner-Bratzler shear force (SF) - gives results within the range from 2.0 to 4.5 of different ostrich meat parts. Marks *et al*. [1998] reported the SF values for ageing ostrich meat to be 10.1, 10.0, 10.0 and 14.1 kg/g for 1 hour, 1 day, 1 week, and for beef control, respectively. The most tender muscles identified were *iliofibularis, iliofemoralis* and *obturatorius lateralis*. Also Sales [1997], indicated that overcooking (cooking at 80°C for 1 hour) can mask the expected decrease in SF value.

Tenderness follows a pattern described by Thomas *et al.* [2004]. It is usually improved through *post-mortem* storage in the refrigerator during process called "conditioning" that, according to Smith *et al.* [1978] takes 8-11 days. In the ostrich, effect of storage of samples in 4°C on toughness occurred until hour 9 *post-mortem* when after that point a decrease until one day occurred. Further, the second increase in tenderness was observed remaining on a constant level until day 12. The same pattern was observed for pH. However, certain authors suggest no need of following this pattern to enhance tenderness of ostrich meat [Botha *et al.* 2006].

It is generally known that connective tissue influences meat tenderness and that this relation is age-dependent. Botha *et al.* [2006] found a positive correlation between deboning with tenderness and ageing with tenderness. Hot- and cold-deboned muscles showed different initial tenderness value 24 hours *post-mortem* and there was a slight difference in the rate of increase in tenderness during 21 days of storage at 4°C between hot- and cold-deboned muscles. Tenderness for both hot- and cold-deboned muscles increased from day 3 to 14 and then until day 42 remained unchanged. In this case ageing caused greatest variation in Warner-Bretzler SF and significantly affected tenderness. SF correlated with pH as in the already mentioned study by Botha *et al.* [2006] – more tender muscles had higher pH. The use of a 9-point hedonic scale and a consumer sensory panel to evaluate tenderness, flavour and overall acceptance of selected cuts, showed that ostrich meat aged for 1 week provided higher scores for flavour compared to less aged ostrich meat or beef control. Ostrich meat may, therefore, provide a good alternative to beef [Cooper and Horbańczuk 2002].

The earlier mentioned method of deboning (cold *vs*. hot) is also an influencing factor. In the study with two types of muscle refrigerated for 42 days and deboned earlier in a cold or hot way, the time of *post mortem* deboning affected the sarcomere length. Deboning 1 h *post mortem* caused hot-deboned muscles to have shorter sarcomeres (2.05 μm) at hour 24 then cold deboned (2.52 μm). Similarly after 1 h, sarcomeres of hot-deboned were shorter than of cold-deboned muscles measured 24 hours *post-mortem* [Botha *et al*. 2006].

Finally, Thomas *et al.* [2004] revealed potential role of proteasome as well as cathepsin B, L, H and D enzymes in the tenderization process, especially in meat characterized by high pH, like ostrich meat. They observed relatively high activity of proteasome after day 12 of storage period. Although the mean SF values showed no simultaneous improvement in tenderness, the cited results suggested a chance for further research in manipulation of tenderization process, especially in ostrich meat.

pH

One of the parameters responsible for meat quality is its pH. On the average, ostrich meat has been classified as intermediate, *i.e*. of pH from regular (<5.8) to high (>6.2) as measured 24 hours post-slaughter [Sales and Mellett 1996]. These values were further confirmed by Otremba *et al.* [1999] and Majewska *et al.* [2009] and make ostrich meat ideal for processing [Sales and Mellett 1996, Fisher *et al*. 2000] even though its high pH could lead to elevated water-holding capacity [Sales 1994]. There are many factors influencing *post-mortem* pH of ostrich meat, among others the slaughter method, stunning, bleeding, deboning, packaging and storage conditions [Lambooij *et al*. 1999, Hoffman *et al*. 2008, 2009].

Post-mortem muscle pH drops rapidly due to glycogenolysis process during which lactic acid is produced. Some ostrich muscles, especially the *ambiens*, *iliofibuaris* and *obturatorius medialis* do not follow usual *post-mortem* pH drop pattern, but they

present rapid drop of pH during first 2 hours and then its increase to stabilization [Balog *et al*. 2006]. Meat quality traits which are related to the *post-mortem* pH decline are mainly: colour, moisture content and shelf life [Balog and Almeida Paz 2007].

Lambooij *et al*. [1999] observed that stunning with air pressure leads to lower pH, especially of leg and breast muscles, compared to low electric shock, where pH has been observed to be the highest after slaughter. This result is similar to that reported by Sales *et al.* [1996], who concluded that ultimate pH in ostrich meat is reached within 2-6 hours *post-mortem*. Due to the fast pH decline of ostrich meat the electric stimulation is not necessary for the meat tenderness improvement [Mellett 1985], although it might be a factor responsible for cold-shortening [Hoffman *et al*. 2008]. Those *post-mortem* pH changes differ ostrich meat from meat of all other red meat-muscled animals.

The effect of an early *post mortem* low-voltage electrical stimulation of carcasses on pH of ostrich meat was recently examined by Hoffman *et al.* [2009]. It resulted in lower pH value after 45 min in the fillet and big drum muscles. However, after 24 hours this effect disappeared when compared to other muscles. Two types of deboning considered here were investigated with regard to their effect on meat pH. Botha *et al.* [2006] indicated that pH_{24} did not differ between hot- and cold-deboned ostrich meat. However, during storage over 42 days significant differences in pH occurred among individual muscles. Hoffman *et al.* [2005] found a positive correlation between ostrich meat pH_{48} and its juiciness: after 48 hours of storage hot-deboned meat was less juicy than cold-deboned. From the same study it was concluded that pH_{48} in hot-deboned samples is negatively correlated with Warner-Bratzler SF, while positively with tenderness evaluated by test panel. Hoffman *et al*. [2005] also observed that hot-deboned muscles differed in pH measured at 1 and 4 hours after slaughter.

Another important pH-influencing factor is further processing (mostly type of packaging) of the meat. Fernandez-Lopez *et al.* [2008] observed that the deepest decline in pH and related decrease in lactic acid bacteria count were in the vacuum-packaged samples as well as in the ones packaged in modified atmosphere. This was in accordance with Gonzalez-Montalvo *et al.* [2007] who reported that pH was lower in vacuum-packaged compared to air-packaged samples after 6 days of observations. Seydim *et al.* [2006], however, suggest that only type of package affects the pH of ostrich meat while the time of storage does not.

Finally, the highest pH value 24 hours *post-mortem* was reported of the darkest meat with lowest percentage of drip loss and cooking loss [Hoffman *et al*. 2008].

Water-holding capacity and drip loss

Water-holding capacity (WHC) is the ability of meat to retain water during applying of external forces, for example cutting, mincing and heating. Appearance before cooking, cooking ability, juiciness during chewing and the total amount of saleable meat are influenced by its WHC [Sales and Horbańczuk 1998]. Lambooij

et al. [1999] reported WHC of ostrich meat to be lower than that of pork and chicken meat [Uijtenboogaart 1997], but similar to veal and beef. However, ostrich steaks are evaluated as drier then beef loin steaks [Harris 1994]. This might be the effect of overcooking the former, which is related to their low intramuscular fat content being the factor loosing up the microstructure. Balog *et al.* [2006] described a relation between WHC and meat texture properties. If not cooked in too high temperature and for too long ostrich meat does not loose too much water what provides it quite high juiciness. Although moisture of ostrich meat is around 75% [Hoffman *et al*. 2005], Walter *et al*. [2000] classified it as dry. They found ostrich meat to be dry and rated lower then beef as a stew or when stir-fried, whether consumers knew the meat origin used in the products or not.

WHC is tightly associated with muscle pH values. Botha *et al.* [2006] reported that the rate of *post mortem* pH drop of muscles affected their WHC. It was also observed that the higher the muscle ultimate pH, the lower is the decrease in WHC [Lawrie 1998]. After reaching a minimum, muscles pH tends to increase with progressing age due to osmotic pressure. In this case WHC increased but denaturation of proteins with time decreased this indicator. It was concluded by Tornberg [1996] that in beef the more shortened muscle showed a higher cooking loss with lower WHC, while peak SF got higher. This was found for hot-deboned ostrich meat, but disappeared in 5 days *post-mortem*. It does not influence the sale chances for that kind of meat because consumers have seldom access to meat sooner than 7 days after slaughter.

There are some discrepancies between results related to WHC and pH_{24} values. Majewska *et al.* [2009] found that none of those parameters differed between muscles. Other authors, however, showed significant intermuscle differences with regard to both indicators [Sales 1996, Hoffman *et al*. 2008]. In case of thawing losses significant differences have been found between muscles (from 1.28 to 4.28%) - Majewska *et al*. [2009].

Otremba *et al.* [1999] found from 3 to 11.5% drip loss for both intact and minced ostrich meat which increased with post-slaughter time and peaked at day 14. It was found by Gonzalez-Montalvo *et al.* [2007] that temperature of storage does not influence this process, although the method of packaging does. Air-packaged samples differed significantly from those packaged in vacuum. Not satisfying results were found on day 3 for vacuum-packaged, day 6 for air-packaged and stored at 10°C and day 9 for air-packaged samples stored at 4°C. Moreover, Hoffman *et al.* [2005] concluded that hot deboning prevents weight loss that occurs due to evaporation during chilling of the meat.

With regard to other meat quality characteristics Thomas *et al.* [2004] observed that the percentage of drip and cooking losses showed opposite trends. When both SF value and percentage of cooking losses increased, the drip loss decreased. Due to the relation between muscle pH and other characteristics, when pH increased, the drip loss decreased. This was related to ostrich meat characterized by dry structure and high pH.

Shelf life and microbial load

Currently, when consumption of ostrich meat shows increasing tendency, improvement of its hygienic safety and extension of shelf-life are crucial, both for the local markets and for export [Gonzalez-Montalvo *et al.* 2007].

pH is the determining factor for meat microbial quality and its shelf life. The characteristic pH value for ostrich meat which is around 6.0 is a good condition for the development of microorganisms resulting in off-odour. Van Schalkwyk *et al.* [2005] observed short shelf life and dark meat colour when a high pH occurred.

Also deboning method can change the shelf life of ostrich meat. Lawrie [1998] found that in hot-deboned muscles where temperature decline is faster then in cold-deboned ones, it results in lower microbial spoilage of meat.

According to Capita *et al* [2006] storage temperature and time both affect the microbial count of meat. The exclusion of oxygen influences total aerobic bacteria count (*Psychrotropic, Pseudomonas*). In the cited study, time of storage influenced all the microbial groups and pH values of ostrich meat. Significant differences in microbial count were reported between day 0 and 9 of storage. Initial pH of the meat in that study was 6.7 and no difference was observed in this parameter between day 0 and 9. It was concluded that poor microbial quality and high pH of ostrich meat post-slaughter could be responsible for high microbial loads during storage. Storage temperature (10°C) of air as well as of vacuum-packaged ostrich meat has significant effect on microbial counts until day 6 of storage. Oxygen exclusion affects the microbial quality of packaged ostrich meat from day 3 of storage. Joint vacuum and low storage temperature improves microbial quality of ostrich meat.

Storage time is of importance for the tenderization process, however, it can also promote an increase in bacteriological load of meat. According to Pollok *et al.* [1997] ostrich fillets packaged under vacuum and refrigerated became unacceptable after 21 days. Otremba *et al.* [1999] came to similar conclusion.

A factor influencing the microbial load and shelf life of ostrich meat is also influenced by method of packing. In the study by Gonzalez-Montalvo *et al.* [2007] microbial counts increased of steak samples inoculated with *Listeria monocytogenes* and *Escherichia coli.* Vacuum-packaged meat presented lower microbial count then air-packaged at 10°C for *Listeria monocytogenes* and at 4 and 10°C for *Escherichia coli*. Storage temperature influenced the bacteria count during time of storage, especially in air-packaged samples. Time until the average general acceptability score was 6 days (sampling day) for air-packaged samples, for 9 and 12 days vacuum-packaged samples stored at 10 and at 4°C, respectively.

Another, already mentioned trial devoted to different ways of packaging ostrich meat was conducted by Fernandez-Lopez *et al.* [2008]. Air-packaged samples of meat showed the highest aerobic bacteria count, while vacuum-packaging reduced this parameter. The count declined for 4 days and then increased in vacuum-packages, MAP and MAP+CO. Concluding, as soon as the spoilage can be detected there is more than 6logCFU/g of bacteria load, while from value 7logCFU/g the meat is

unacceptable. For ostrich meat those values are reached by samples stored under air conditions for 8 days and under modified atmosphere for 12 days.

In South Africa there is a common practice to keep vacuum-packaged ostrich steaks for more than 40 days in <1°C. Botha *et al.* [2006] observed smaller microbial growth compared to other studies - Otremba *et al*.[1999] - due to lower temperature of storage (-3 to 0°C) during 42 days. Hot-deboning in an hour *post-mortem* caused increased bacteria count prior to vacuum-packaging. However, higher temperature and longer conditioning periods prior to application of vacuum and chilling may adversely affect the meat microbial quality and that is why hot deboning and vacuum during slaughter need careful control. Although ostrich muscles attain higher pH throughout *post-mortem* storage and may undergo higher risk of microbial spoilage, the microbial tests indicate that both hot- and cold-deboned muscles are suitable for export after 42 days.

Cold shortening

Cold shortening is the muscle response when exposed to temperatures below 10°C at pH>6.2, causing toughening of the meat when cooked. In the ostrich the meat cold shortening has been reported to undergo the intermuscle variation [Sales and Mellet 1996]. Muscles excised from carcass 30 min after bleeding and subjected to cooling at 0-4°C for 12 hours were evaluated by measuring sarcomere length [Sales and Horbańczuk 1999]. Only *m. iliotibialis* and *iliofemoralis* showed high frequency of shortened sarcomeres (20-40%) and presented SF similar to other muscles. These results indicate the absence of cold shortening in ostrich muscle due to the leg removal from the carcass shortly after bleeding because there is no stress put on those muscles. Moreover, Hoffman *et al.* [2008] found that hot-deboned muscles took longer to reach the minimum pH than the intact muscles. However, no risk of cold shortening was observed also by these authors for ostrich muscles if they were hot-deboned 2-4 hours *post-mortem*. Rates of cooling were observed to be rapid in hot-deboned and vacuum-packaged meat cuts compared to muscles left on carcass. Therefore, cold shortening and toughening of meat would be more readily induced in hot-deboned muscles than in muscles left on carcass refrigerated in the same temperature [Lawrie 1998]. Generally, in the ostrich meat there is a rapid *post-mortem* decline in pH. The pH value of <6.2 is reached in 2-4 hours while muscles still have >10°C. This causes no risk of cold shortening if muscles were excised early *post-mortem*.

Cooking losses

Hoffman *et al.* [2008] reported that SF was highly correlated with percentage of cooking loss. The reason for that is collagen, which is the principal fibrous protein of the connective tissue [Tarrant 1998]. When exposed to heat (65°C) collagen contracts to one quarter of the original length and becomes rubber-like [Bailey and Sims, 1997].

This increases tension and fluid is exuded from the muscle resulting in the increase of toughness.

In the literature the favoured relation is described between cooking loss and tenderness of meat [Silva *et al*. 1999, Thomas *et al*. 2004]. Increase in tenderness and decrease in cooking loss depend on the diluting effect of the bound water. The amount of fibre found in the given area is less when more water is bound.

A significant correlation between meat pH and cooking loss through 21 days of ageing was observed by Botha *et al.* [2006]. They reported that as the pH decreased with progressing ageing time the cooking loss increased. Moreover, hot deboning did not affect the cooking loss from hot- and cold-deboned muscles at 1 hour *post-mortem*. Cooking loss increased significantly as ageing time increased. Finally, higher purge is related to higher cooking loss as the ageing time increases.

Acknowledgements*. The authors are grateful to Professor J.O. Horbańczuk and Dr Ross Gordon Cooper for valuable comments to the manuscript.*

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