Effect of drying air temperature and slice thickness on the physical and microbiological quality of dried beef

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Abstract

The aim of this study was to investigate the influence of cabinet drying air temperature (30–60 °C) and sample thickness (2.5–10 mm) on the quality attributes of dried beef. The physical (colour, rehydration ratio/RR and texture) and microbial quality of beef samples were evaluated using standard procedures. There was a significant decrease (P ≤ 0.05) in L*, a*, b* and chroma/C* colour values with increasing temperature and beef thickness, while change in thickness had no effect (P > 0.05) on the hue/H* colour attribute. The RR was higher at 60 °C for 5–10 mm thick samples and decreased (P ≤ 0.05) with increase in beef thickness. The firmness values increased with increase in temperature from 30 to 50 °C, decreased at 60 °C and were significantly lower (P ≤ 0.05) at 2.5 mm beef thickness. The total viable counts (TVC) and Staphylococcus aureus numbers in beef dried at 30 and 40 °C were higher than that of fresh beef, whereas drying at 60 °C significantly (P ≤ 0.05) reduced the microbial numbers.

1. Introduction

Meat is the edible part of the skeletal muscle of an animal that was healthy before slaughter (CFDAR, 1990, p. 64). It is preferred as protein source by most people throughout the world due to its distinct flavor and rich nutrient matrix. However, meat is highly perishable, and the lack of proper preservation techniques in the tropics has led to post-slaughter losses; excess meat gets wasted and cannot be stored for use in times of shortage. Sun drying has been practiced for many years and has been used by nomads and pastoralists to preserve meat during excess times of shortage. Sun drying has been practiced for many years and has been used by nomads and pastoralists to preserve meat during excess supply (FAO, 1995). However, it is no longer recommended due to lack of a steady heat source thus difficulty in controlling the drying process. It could also be very time-consuming, with a high risk of contamination from animals, insects, dust, and bacteria (Park, Lee, & Jeong, 2002).

Convective hot-air dryers are commonly employed for the industrial processing of various agricultural products in most developing countries. These drying systems reduce food spoilage by sufficiently reducing water activity of products, thus inhibiting microbial growth. However, hot-air drying may result in changes to the physico-chemical quality of meat (FAO, 1995) with temperature being the most influencing factor. Most changes in meat during drying result from protein denaturation. Especially, denaturation of heme proteins and oxidation of myoglobin pigments which cause darkening of products (Haard, 1992). Protein denaturation also leads to decreased water holding capacity and shrunken muscle fibers, creating a harder and more compact tissue texture (Harris & Shorthose, 1988). These changes in physical structure as well as the chemical properties of meat, as a result determine its ability to rehydrate, or return to its original weight when immersed in water (Farkas & Singh, 1991).

Muscles of healthy animals are regarded as sterile, but the slaughtering and butchering process creates an opportunity for bacteria to colonize meat surfaces (Olajye, 2011). The initial microbial load on surfaces of meat to be dried is determined by the hygiene of the abattoir and the handling practices of the meat during butchery and preparation of strips for drying (Mothershaw, Rahman, Mohammed, & Guizani, 2003). Subsequently, the presence of microorganisms in the product determines both its shelf-life and safety. The pathogens of interest in fresh and frozen meat and meat products are: Salmonella spp., Staphylococcus aureus, Listeria monocytogenes, Escherichia coli, Yersinia enterocolitica, Campylobacter spp. and Clostridium perfringens (Mor-Mur & Yuste, 2010).

With an increasing demand for high quality dried products that retain their natural characteristics (Fernandes, Rodrigues, Law, & Mujumdar, 2011) and consumer expectation for minimally processed, convenient and safe food products, solar drying is gaining a lot of interest. However, in order to optimize the drying process in tropical solar drying conditions, information on dried beef quality in conditions close to that of the real process is needed. The process of beef dehydration...
during salting and drying at low temperature conditions and its effect on quality has been examined (Chabbouh et al., 2011). Whereas pre-treatment by salting is a common practice for traditional dried meat products in Kenya (Gichure, Kunyang, Mathi, & Imungi, 2014), consumers increasingly require low salt or unsalted foods. Furthermore, dried unsalted meat is more suitable for use as an ingredient in new product development. The present study was therefore undertaken to compare the effects of cabinet air drying temperatures and unsalted beef slice thickness on the color \((L^*, a^*, b^*, H^*, C^*)\), texture, rehydration ratio and microbiological quality of the dried product.

2. Materials and methods

2.1. Sample collection and preparation

Meat (beef) of high microbial quality from the round of the hind quarter of an inspected male carcass was purchased from Dagoretti slaughter house, Nairobi, Kenya. Excess fat was trimmed off to prevent rancidity while drying. It was then cleaned and stored in a cold room at 5 °C for 48 h prior to experiments so that the storage conditions would be the same for all samples before drying. The meat was frozen overnight to obtain enough consistency for cutting and cut along the direction of its fibers into thin strips of 100 mm long, 30 mm wide and varying thicknesses of 2.5, 5.0, 7.5 or 10 mm. The average moisture content of fresh beef was 76.67%.

2.2. Experimental design

Drying experiments were carried out using a bench top cabinet dryer “Hohenheim HT mini” (Innotoch-ingenieurgesellschaft mbH, Altdorf, Germany) at 30, 40, 50, and 60 °C air temperatures and air flow generated by a fan which was set at a constant voltage of 24 V. For each drying run, about 220 g of the meat pieces with varying slice thicknesses were spread out in a single layer on perforated trays. The drying experiments were repeated 3 times at each temperature and slice thickness and dried to 10–20% moisture content (dry basis), representing the moisture content of traditional dried meats of tropical countries (Kalilou, Collignan, & Zakhia, 1998). This corresponds to a water activity less than 0.6 in the experimental temperature range (Ahmat, Bruneau, Kuitche, & Aregba, 2014).

2.3. Colour determination

Colour measurements were performed at room temperature (25 °C) using a hand held tri-stimulus colorimeter (Minolta Chroma Meter CR-220, Minolta Co., Osaka, Japan) with an 8 mm diameter measuring area. The instrument was calibrated on the Hunterlab colour space system using a white reference tile \((L^* = 97.50, a^* = -0.60 \text{ and } b^* = 2.30)\) and a D65 illuminant source before the measurements. For each sample three dried strips from each replicate were placed as a single layer on a flat plate, and the tip of the colorimeter measuring head pointed at the sample surface, eight consecutive measurements were taken on different areas of the surface. The \(L^*, a^*\) and \(b^*\) colour coordinates were determined according to the ISO/CIE standard color space system proposed by Commission Internationale de l'Éclairage (Joint ISO/CIE Standard, 2008), where: \(L^*\) is the lightness or darkness (black, \(L^* = 0\); white, \(L^* = 100\)), \(+a^*\) is the redness, \(-a^*\) is the greenness, \(+b^*\) is yellowness, and \(-b^*\) is the blueness.

In addition, the hue-angle \(h^\circ\) and saturation index or chroma \(C^\circ\), which describe the hue colour \(H^\circ\) and brightness or vividness of color, respectively, were calculated using Equations (1) and (2) according to AMSA (2012) guidelines:

\[
h^\circ = \tan^{-1}\left(\frac{b^*}{a^*}\right)
\]

\[
C^\circ = (a^2 + b^2)^{0.5}
\]

2.4. Rehydration ratio assessment

To calculate the rehydration ratio, the dried sample was weighed, immersed in a hot water bath at 100 °C for 10 min, drained and re-weighed. The rehydration ratio was then calculated as shown in Equation (3). The procedure was conducted in triplicate for each sample.

\[
RR = \frac{M}{M_0}
\]

where; \(RR\) is the rehydration ratio, and \(M\) and \(M_0\) are the sample weights after and before placing in the hot water bath, respectively.

2.5. Texture measurement

Texture measurements were done for dried beef using a TA.XT.plus Texture Analyzer (Stable Microsystems, Surrey, UK) with the Volodkevich bite jaws (HDP/VB+) fixture. This fixture performs an imitative test by simulating the action of an incisor tooth biting through food. It comprises upper and lower jaws which are fitted to the load cell and Heavy Duty Platform. A sample is positioned in the lower jaw and the biting action is provided by the compressive movement of the upper jaw shearing into the meat (Hansen, Hansen, Aadlyng, & Byrne, 2004). The Volodkevich test was carried out at a deformation rate of 100 mm/min to give the maximum shear force (N). The pre-test-speed, test speed, and post-speed were set at 5.0 mm/s, 5.0 mm/s and 2.0 mm/s respectively, and the compression distance was set at 25%. Height calibration was 10 mm above the sample. A 50 kg load cell was used to compress the samples. Pieces of dried beef samples measuring 1 cm² (square cross-section), were placed parallel to the compression plate surface and compressed.

2.6. Microbial analysis

Meat samples (25 g) were mixed in sterile glass jars containing 225 ml of sterile 0.85% saline solution for 2 min. Decimal serial dilutions were prepared. Subsequently, 0.1 ml aliquots of each dilution were spread over the surface of plates in triplicates. Culture media and incubation conditions used for the different microbial groups were as follows: total viable count on pour plates of plate count agar (PCA) at 35 °C for 48 h-AOAC official method 966.23 (AOAC, 2000); Staphylococcus aureus on Baird-Parker agar at 35 °C for 48 h (Baird-Parker, 1962); Salmonella on Xylose-Lysine-desoxycholate (XLD) agar at 35 °C for 24 h (Taylor, 1965); Enterobacteriaceae on Violet Red Bile Glucose (VRBG) agar at 35 °C for 24 h (Mossel, Elederink, Koopmans & Van Rossem, 1978) and Listeria monocytogenes on Listeria selective medium at 35 °C for 24 h (Curtis, Mitchell, King & Griffin, 1989). The results were expressed as Log₁₀ colony-forming units per gram (Log₁₀ CFU/g) of dried meat. All media were purchased from Oxoid (Basingstoke, Hampshire, England, UK).

2.7. Statistical analysis

In order determine the effects of experimental variables (drying air temperature and beef slice thickness) on beef quality parameters; a \(4 \times 4\) factorial design was used. The data were analysed using MINITAB version 16 software (Minitab Inc, Pennsylvania, USA). Analysis of variance was carried out and the P-value used to determine significance of main effects and interaction between variables at \(\alpha \leq 0.05\), \(\alpha \leq 0.01\) or \(\alpha \leq 0.001\). To establish differences between means, the experiments were designed as a single factor completely randomized design. The results were subjected to one-way analysis of variance and differences in treatment means identified at \(P \leq 0.05\) by Duncan’s Multiple-range test.
Table 1
Effect of drying temperature and sample thickness on beef colour parameters.

<table>
<thead>
<tr>
<th>Dried beef</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>H*</th>
<th>C*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh beef</td>
<td>32.70 ± 2.10f</td>
<td>14.70 ± 1.19b</td>
<td>7.74 ± 0.64l</td>
<td>27.90 ± 3.80Ab</td>
<td>16.60 ± 0.77b</td>
</tr>
<tr>
<td>temp (°C)</td>
<td>thickness (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.25</td>
<td>26.20 ± 3.50f</td>
<td>8.88 ± 2.00f</td>
<td>4.10 ± 2.08f</td>
<td>25.00 ± 6.56b</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>25.70 ± 1.78d</td>
<td>5.78 ± 1.52c</td>
<td>2.85 ± 1.46g</td>
<td>25.10 ± 6.14bc</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>25.30 ± 2.73d</td>
<td>4.70 ± 0.93f</td>
<td>2.75 ± 0.94d</td>
<td>30.00 ± 8.36d</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>23.60 ± 0.68bc</td>
<td>2.90 ± 0.53</td>
<td>2.60 ± 1.74d</td>
<td>38.60 ± 12.47bc</td>
</tr>
<tr>
<td>40</td>
<td>0.25</td>
<td>25.90 ± 1.41e</td>
<td>7.69 ± 1.56f</td>
<td>3.72 ± 1.38h</td>
<td>25.30 ± 5.20h</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>24.90 ± 1.80bcd</td>
<td>4.56 ± 1.17d</td>
<td>2.37 ± 0.75bc</td>
<td>28.00 ± 9.82d</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>24.00 ± 3.71bc</td>
<td>2.66 ± 0.67bc</td>
<td>1.08 ± 0.30bc</td>
<td>22.20 ± 4.25h</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>23.60 ± 2.70bc</td>
<td>2.53 ± 1.48bc</td>
<td>1.54 ± 0.74bc</td>
<td>32.50 ± 17.68bc</td>
</tr>
<tr>
<td>50</td>
<td>0.25</td>
<td>25.90 ± 2.31e</td>
<td>5.63 ± 0.89fg</td>
<td>3.51 ± 1.19bc</td>
<td>31.10 ± 5.45bc</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>23.90 ± 1.99bcd</td>
<td>4.43 ± 0.61d</td>
<td>2.30 ± 0.40d</td>
<td>27.60 ± 5.02b</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>23.40 ± 2.63bc</td>
<td>2.50 ± 0.52bc</td>
<td>1.00 ± 0.36bc</td>
<td>22.20 ± 8.97h</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>22.40 ± 1.91f</td>
<td>2.25 ± 0.82bc</td>
<td>1.46 ± 0.69bc</td>
<td>33.30 ± 13.32bc</td>
</tr>
<tr>
<td>60</td>
<td>0.25</td>
<td>25.50 ± 2.52def</td>
<td>2.98 ± 0.44f</td>
<td>3.28 ± 0.96bc</td>
<td>47.00 ± 5.66d</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>23.00 ± 2.08bc</td>
<td>1.79 ± 0.74ab</td>
<td>2.22 ± 0.66b</td>
<td>45.60 ± 12.03d</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>22.70 ± 3.08bc</td>
<td>2.01 ± 0.71ab</td>
<td>2.08 ± 0.56b</td>
<td>46.60 ± 12.03d</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>22.40 ± 2.02b</td>
<td>1.66 ± 0.77b</td>
<td>1.76 ± 0.64bc</td>
<td>46.50 ± 14.97dc</td>
</tr>
<tr>
<td>Effect</td>
<td>temp</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>thickness</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>temp x</td>
<td>NS</td>
<td>***</td>
<td>NS</td>
<td>*</td>
</tr>
</tbody>
</table>

Means in the same column with the same superscripts are not significantly different at P > 0.05. Treatment effects significant at *P < 0.05; **P < 0.01; ***P < 0.001; NS not significant at P > 0.05.

Test using GenStat Edition 13 software (VSN International Ltd, UK). All the experiments were replicated three times.

3. Results and discussion

3.1. Colour

Mean colour parameter values of fresh beef and samples dried at different experimental conditions are given in Table 1. The temperature and slice thickness effects on colour parameters are also given. Fresh beef had values of 32.70 ± 2.10, 14.70 ± 1.19, 7.74 ± 0.64, 27.90 ± 3.80 and 16.60 ± 0.77 for L*, a*, b*, H* and C* respectively (Table 1). Similar results were reported by Teixeira, Pereira, and Rodrigues (2011) for air dried goat meat. Increasing beef thickness during drying significantly decreased the L*, a*, b* and C* colour parameters but had no effect (P > 0.05) on the H* colour attribute.

The lightness (L*) values of dried beef at all experimental conditions ranged from 22.40 ± 2.02 to 26.20 ± 3.50. The L* value indicates the extent of browning of dried samples; a higher L* value showing less brown color of the product (Rahman, Al-Amri, & Al-Bulushi, 2002). The reduction of L* values showed that drying at a higher temperature caused significant protein structural changes of meat samples (Lawrie, 1998, pp. 178–199). This could have been caused by the Maillard browning reactions resulting from the reaction between amine groups of muscle proteins and available reducing sugars in connective tissues during heat processing of meat products (Forrest, Aberle, Hedrick, Judge, & Merkel, 1975). The decrease in L* values with meat thickness was due to the longer drying time and the longer exposure of the beef to the drying medium resulting in more browning of sugar-amine.

The redness (a*) values of dried beef ranged from 1.66 ± 0.77 to 8.88 ± 2.00. The decrease in redness (a*) values with temperature was more significant (P < 0.05) at a lower meat thickness (2.5 mm). A significant interaction (P ≤ 0.001) between drying air temperature and beef thickness on reduction of redness (a*) and red intensity as noted by saturation index (C*) was also observed (Table 1). The redness of meat is due to the presence of myoglobin, which is the most important meat pigment (Hedrick, Aberle, Forrest, Judge, & Merkel, 1994). Surface discoloration in fresh meat is mostly as a result of metmyoglobin formation (Renerre, 1990), which is an oxidised form of myoglobin. The rate of myoglobin oxidation is greatly accelerated by temperature increase (Yin & Faustman, 1993), causing a reduction in redness of meat.

The L*, a* and b* values, indicate the degree of browning during drying as well as a source of variation in light scattering from the surface of meat (Van Oeckel, Warnants, & Boucke, 1999). However, the H* and C* values, calculated from the CIE a* and b* values provide greater sensitivity than L* a* and b* values alone (Little, 1975). The hue colour of beef dried at 60 °C was significantly higher (P < 0.05) than samples dried at lower temperatures (Table 1). Hue (H*) is the colour description as communicated in language (red, yellow, green, blue) (AMSAS, 2012). Larger H* values in meat indicate less red, more metmyoglobin formation and a more well-done cooked color (Howe, Gullett, & Usborne, 1982).

3.2. Rehydration ratio

Both temperature and sample thickness had highly significant (P ≤ 0.001) effects on the rehydration ratio of beef whereas the interaction effect was not significant (P > 0.05) (Table 2). Rehydration refers to the process of moistening a dried product and is an indicator of cellular and structural disintegration that occurs during dehydration (Rastogi, Angersbach, Niranjan, & Knorr, 2000). Changes in
Table 2: Temperature and thickness effects on rehydration ratio and beef firmness.

<table>
<thead>
<tr>
<th>Effects</th>
<th>Rehydration Ratio</th>
<th>Beef Firmness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Thickness</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Temperature x Thickness</td>
<td>NS</td>
<td>***</td>
</tr>
<tr>
<td>r²</td>
<td>0.86</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001; NS not significant at P > 0.05.

Rehydration ratios of beef when dried under different temperature conditions and sample thicknesses are shown in Fig. 1. The rehydration ratio was significantly higher (P ≤ 0.05) at 60 °C for dried beef with thicknesses of 5.0, 7.5 and 10 mm, while there was no significant difference (P > 0.05) in rehydration ratios for samples with 2.5 mm thickness at all the drying temperatures.

The rate and extent of water uptake during rehydration of meat is greatly influenced by the cellular and structural arrangements in the food matrix since this provides the channels for transporting water to muscle fibers (Niamnuy, Devahastin, & Soponronnarit, 2014). During heating, the different meat proteins denature and cause meat structural changes, such as the destruction of cell membranes, transverse and longitudinal shrinkage of muscle fibres, aggregation and gel formation of sarcoplasmic proteins and shrinkage and solubilization of connective tissue fibres (Tornberg, 2005). The transverse shrinkage of muscle fibres occurs mostly at 40–60 °C, while the connective tissue fibres and the muscle fibres cooperatively shrink longitudinally at 60–70 °C, leading to larger extracellular voids (Tornberg, 2005). This, together with solubilization of connective tissues could explain the increased water uptake during rehydration of dried beef at 60 °C.

There was a significant decrease (P ≤ 0.05) in rehydration ratio with increase in meat thickness at all drying temperatures (Fig. 1). This may have been due to the fact that the rate of moisture removal from meat with a higher thickness value was slower, thus increasing the drying time and exposure to high temperature. This enhanced denaturation of myofibrillar and collagenous connective tissue proteins, making them lose their water holding ability (Nathakaranakule, Kratwanichkul, & Soponronnarit, 2007) and resulting in loss of ability to reconstitute faster.

3.3. Texture

Fig. 2 shows beef firmness (N) values as affected by slice thickness and drying temperature. Both temperature and slice thickness had a significant effect (P ≤ 0.001) on the texture of beef. The interaction effect was also highly significant (P ≤ 0.001) (Table 2). However, there was no significant effect (P > 0.05) of temperature on firmness values at higher beef thicknesses (5–10 mm) and the effect of drying temperature was more pronounced at beef thickness of 2.5 mm. Texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetic. Its components include; hardness, firmness/softness, crispness, juiciness, mealliness/grittiness and toughness/fibrousness (Szczechniak, 2002).

The firmness values of dried beef increased with an increase in temperature from 30 to 50 °C then decreased at 60 °C (Fig. 2). Texture changes during processing are caused by complex chemical changes on the muscle fibers and connective tissue fibers. The variation of texture within a temperature range of 40–75 °C and the effect of heat-induced denaturation of meat proteins at varying temperatures was reported by Davey & Gilbert (1974). Heating meat to around 50 °C yields an increased toughness, which has been attributed to myofibrillar denaturation (Bouton & Harris, 1972). The improved tenderness of meat at 60 °C is related to collagen denaturation (Bouton & Harris, 1981), although there has been speculations of effect of increased prolytic activity in beef muscles (Davey & Niederer, 1977) resulting in meat tenderization.

The Volodkevich firmness values were significantly lower (P ≤ 0.05) at meat thickness of 2.5 mm. This could be because the longer drying time caused the thicker meat slices to be exposed to heat for longer; as a result, the muscle fibers were more shortened (Sa-Adchom, Swadisdevi, Nathakaranakule, & Soponronnarit, 2011) giving a much denser material and tougher meat. The size of the meat could also have influenced the firmness values due to the higher compression force required to deform thicker meat.

3.4. Microbial quality

Table 3 shows the results obtained from the quantification of bacteria in the fresh and dried beef samples evaluated immediately after drying. No significant growth (< 2.00 ± 0.00 log10cfu/g) of Enterobacteriaceae was observed, while Salmonella spp and Listeria monocytogenes were not detected in any of the samples. Generally Enterobacteriaceae and Listeria species are mostly good indicators of hygiene and post-process contamination of heat processed foods (FSA, 2001; Wang & Muriana, 1994).

Fresh beef had an aerobic plate count of 4.89 ± 0.01 log10 cfu/g (Table 3). The beef samples used for drying were taken from chilled and frozen cuts, which could have enhanced microbial growth. Good hygiene and handling practices are usually more important for meat that is frozen and thawed than unrefrigerated meat (Pham, 2004), owing to the fact that thawing is a slower and less uniform process than freezing, creating more favourable temperature conditions for microbial growth. The structural disarray caused by the freezing process, results in exudate formation during thawing. This nutrient dense moisture also provides an excellent medium for microbial growth (Leygonie, Britz, &
Hoffman, 2012). The numbers of *Staphylococci* present in the fresh meat were high, 4.65 ± 0.05 log_{10} cfu/g of beef (Table 3). These species are naturally found in humans and the high levels found in fresh meat was attributed to the excessive handling of the meat samples during preparation for drying, to ensure uniform strips were prepared to reduce experimental error (Mothershaw et al., 2003).

The effect of temperature, beef slice thickness and the interaction between the variables on the TVC and numbers of *Staphylococci* on dried beef samples was highly significant (P ≤ 0.001) (Table 3). The TVC counts in beef dried at 30, 40 and 50 °C (at 2.5 and 5.0 mm meat thicknesses) were significantly higher (P ≤ 0.05) than that of fresh beef. The increase in bacterial counts could be explained by the effect of low temperature drying for a longer time. The thickness of meat determines the duration of drying and therefore the length of exposure of microorganisms to the drying medium. The *Staphylococci* were also resistant to drying at these low temperatures (30–50 °C); their numbers were highest (7.08 ± 0.03 log_{10} cfu/g) for beef samples with 10 mm slice thickness, dried at 30 °C (Table 1).

This suggests that during the initial stages of low temperature drying, the *Staphylococci* continued to increase in numbers until water activity (a_w) was reduced to below about 0.86 (Dave & Ghaly, 2011). *Staphylococcus aureus* is one of the most common food borne pathogens causing food poisoning and the minimum number of cells required to produce enterotoxin is about 7.00 log_{10} cfu/g (Mossel & van Netten, 1990). Consequently the high numbers detected are a potential health risk.

4. Conclusion

Increasing the drying temperature has a significant effect on all the colour parameters, increasing H* and decreasing L*, a* and b* values and therefore decreases the acceptability of dried beef. Drying of beef at 60 °C produces a product with the highest rehydration ratio compared to drying at lower temperatures. Rehydration ratio of dried beef decreases with increase in meat thickness at all drying temperatures. Firmness of dried beef increases with increase in temperature from 30 to 50 °C then decreases at 60 °C at a thickness below 5.0 mm but is not affected by temperature at higher thicknesses. The lowest firmness of dried beef occurs at a slice thickness of 2.5 mm. Drying at 60 °C is most effective in reducing bacterial numbers when compared to lower drying temperatures.

**Acknowledgement**

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**References**


Baird-Parker, A. C. (1971). General, drying at the lowest temperature significantly increased (P ≤ 0.05) the microbial flora approximately 2–3 log cycles and drying at 60 °C was the most effective drying process for reducing microbial numbers.


Bouton, P. E., & Harris, P. V. (1981). Changes in the tenderness of meat cooked at 50-65