RUFORUM Working Document Series (ISSN 1607-9345), 2018, No. 17 (1): 251-257.
Available from *http://repository.ruforum.org*

Research Application Summary

Effect of solar tunnel drying on the instrumental texture parameters of dried beef

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Abstract

Drying causes many changes to the various quality properties of meat and meat products, including texture. Most of the textural changes in meat during drying are due to denaturation of meat proteins which results in different structural changes. The aim of this study was to determine the effect of solar tunnel drying on the different textural parameters of dried beef. The beef samples were dried in different sections of the solar tunnel dryer (A-D, from the collector end to the end of the drying chamber of the tunnel dryer, respectively) and in the open sun as the control. The textural parameters of the dried product were then determined using volodkevich bite jaws and texture profile analysis methods of the texture analyser as well as the puncturing method of the rheometer. The hardness and firmness values of the dried beef samples were used to assess the level of variability of the three texture-measuring instruments and other textural parameters evaluated by texture profile analysis (TPA). The puncture test hardness values were significantly lower ($P \leq 0.05$) than the values found for all the test methods used and were approximately ten times lower than the volodkevich firmness values. The TPA test could only be done on rehydrated samples resulting in a lower force of compression compared to the force required to deform samples for the volodkevich test. However, there was a high level of variability of the results as given by the large values of standard deviation of the TPA samples. The difference between the other textural parameters of the sun and solar dried beef samples was mostly significant for the sample closest to the collector end of the solar drier (sample A). Its adhesiveness, springiness (%) and resilience texture parameters were higher compared to sun dried beef samples.

Key words: Dryer sections, firmness, hardness, meat, texture-measuring instruments, texture profile analysis

Résumé

La plupart des changements de texture de la viande pendant le séchage sont dus à la dénaturation des protéines de viande qui entraîne différents changements structurels. Le but de cette étude était de déterminer l'effet du séchage du tunnel solaire sur les différents paramètres de texture du bœuf séché. Les échantillons de bœuf ont été séchés dans différentes sections du séchoir à tunnel solaire

(A-D, de l'extrémité du collecteur à l'extrémité de la chambre de séchage du séchoir à tunnel, respectivement) et au soleil en tant que témoin. Les paramètres de texture du produit séché ont ensuite été déterminés en utilisant les mâchoires de morsure de Volodkevich et les méthodes d'analyse de profil de texture de l'analyseur de texture ainsi que la méthode de perforation du rhéomètre. Les valeurs de dureté et de fermeté des échantillons de bœuf séché ont été utilisées pour évaluer le niveau de variabilité des trois instruments de mesure de texture et d'autres paramètres de texture évalués par analyse de profil de texture (TPA). Les valeurs de dureté du test de perforation étaient significativement plus faibles ($P \leq 0{,}05$) que les valeurs trouvées pour toutes les méthodes d'essai utilisées et étaient approximativement dix fois inférieures aux valeurs de fermeté volodkevich. Le test TPA ne pouvait être effectué que sur des échantillons réhydratés, ceci entraînant une force de compression inférieure à la force requise pour déformer les échantillons au séchage qui provoque de nombreux changements dans les diverses propriétés de qualité de la viande et des produits carnés, y compris la texture pour le test volodkevich. Cependant, il y avait un niveau élevé de variabilité des résultats comme donné par les grandes valeurs de l'écart type des échantillons TPA. La différence entre les autres paramètres de texture du soleil et les échantillons de bœuf séché au soleil était surtout significative pour l'échantillon le plus proche de l'extrémité collecteur du séchoir solaire (échantillon A). Ses paramètres textural d'adhésivité, d'élasticité (%) et de résilience étaient supérieurs à ceux des échantillons de bœuf séchés au soleil.

Mots clés: Sections de séchoir, fermeté, dureté, viande, instruments de mesure de texture, analyse de profil de texture

Introduction

The most consumed meat product in sub-Saharan Africa is beef. Its production is highest in South Africa, Kenya, Egypt, Nigeria, Sudan and Morocco, respectively (FAOSTAT, 2016). More than 50% of livestock population in Kenya is found in the arid and semi-arid lands under the pastoral production system, which provides the bulk of meat consumed in the country. However, due to the lack of cold storage facilities and climatic conditions in these areas, it is essentially not possible to preserve meat or meat products for any length of time. Meat has a rich nutrient matrix and high water activity, thus highly perishable and can undergo deterioration from time to time. This can result in post-harvest losses which can be as high as 50% of the meat produced, leading to food insecurity and reduced profit margins to value chain actors in Kenya

It is therefore, necessary to adopt technologies which can effectively reduce the post-harvest losses by applying appropriate methods of post-harvest handling, processing and preservation. Some of the new meat preservation technologies that have been used in research include hot-air drying, superheated steam drying, vacuum drying and freeze drying. However, due to their energy requirements, these technologies are not applicable and affordable to most farmers in the arid and semi-arid areas. Sun drying is commonly practiced in the developing countries as a method of meat preservation and is still preferred due to the use of solar energy which can serve as a sustainable energy source, is renewable and environment friendly (Xie *et al.,* 2011). However, the method exposes the product to contamination by dirt, dust, insects and bacteria causing significant reduction of product quality. Solar drying can therefore be done as an alternative to open sun drying as it is a promising and attractive application of solar energy systems. This technology is suitable for use in the pastoral areas of Kenya as there is abundant supply of solar energy.

As much as solar tunnel drying of food products is gaining a lot of interest as an elaboration of sun drying and an efficient system of utilizing solar energy in different regions of the tropics and subtropics, most of the studies on experimental investigations and quality of dried food products have focused on fruits and vegetables (Hossain and Bala, 2006; Sacilik *et al.,* 2006). Research on quality of dried beef after solar tunnel drying is limited. This research therefore, studied effect of sun and solar tunnel drying on the textural parameters of dried beef. However, due to the irregular structure of dried meat products and variability in meat texture analysis methods (Salakova, 2012), three texture measuring instruments were used to evaluate the firmness, hardness and other texture parameters of solar and sun dried beef samples.

Materials and Methods

Sample collection and preparation. Meat (hind leg beef) with a moisture content of 76.69%. was sourced from a local butchery in Isiolo county, Kenya and stored in a freezer overnight to have enough consistency for cutting. The beef was deboned after fat removal then sliced into approximately 5.0 mm thick strips with a mechanical slicer (Bizerba GmbH & Co.Kg., Balingen, Germany).

Drying equipment and drying methods. A Hohenheim type solar tunnel dryer installed at Ewaso Ng'iro North Development Authority (ENNDA), Isiolo county, Kenya was used to dry beef samples. The dryer was divided into four sub-sections and the samples within each section named A, B, C and D from the collector end to the end of the drying chamber of the tunnel dryer respectively in order to determine the effect of sample position on the quality of the dried product. The samples were spread as a single layer on trays (layered with plastic nets) which were loaded into the different sections of the drying chamber. Each experiment was started after completion of loading (at 9:00 a.m) and discontinued at 4:00 p.m.

To compare the performance of the solar tunnel dryer with that of open sun drying, control samples of beef were spread out in a tray as a single layer and placed on a raised platform beside the dryer allowing air to pass from beneath the tray. Both experimental and control samples were dried simultaneously under the same weather conditions. During the drying period, the ambient temperature, ambient relative humidity, inlet air velocity and solar radiation intensity varied from 21.3-38.9 °C, 48-69.5%, 0.02-0.18 m/s and 476.3-1000 W/m^2, respectively. Temperature profile along the tunnel dryer varied from 42.6 to 64.6, 42 to 64.8, 41.5 to 63.4, 40 to 62.5 and 36.1 to 60.1 °C at the inlet of section with samples A to the outlet of section with samples D of the solar tunnel drier, respectively. The dehydration processes were done in duplicates and completed on the second day after a total drying time of 11 h for both drying methods. The dried beef samples were collected, cooled in a room to ambient temperature and packaged in low density polyethylene bags for quality evaluation before storage.

Instrumental texture

Volodkevich bite jaws firmness. Texture (firmness) measurements for the dried beef samples were done using a TA.XT.plus Texture Analyzer (Stable Microsystems, Surrey, United Kingdom) with the volodkevich bite jaws (HDP/VB*) fixture. This fixture comprises upper and lower jaws which are fitted to the load cell and Heavy Duty Platform. It performs an imitative test by simulating the action of an incisor tooth biting through food. A sample is positioned in the lower jaw and the compressive movement of the upper jaw shearing into the meat provides the biting action. The volodkevich test was carried out at a deformation rate of 100mm/min. The pre-test speed, test speed, post-test speed, trigger force and the compression distance were set at 5.0 mm/s, 5.0 mm/s 2.0 mm/s, 5g and 25 % respectively. A 50 kg load cell was used to compress the samples. Pieces of dried beef measuring 1 cm^2 (square cross-section), were placed parallel to the compression plate surface and compressed.

Rheometer puncture test. To measure hardness of dried beef, puncture test was done using a Rheometer (Sun Rheometer Compaq-100, Sun Scientific co. ltd, Japan) equipped with a cylindrical probe with a diameter of 5 mm. Samples were punctured at a distance of 3 mm with a test speed of 500 mm/min and a load cell of 10 kg.

Texture profile analysis. Texture Profile Analysis (TPA) of rehydrated beef samples was done using a TA.XT.plus Texture Analyzer (Stable Microsystems, Surrey, United Kingdom), equipped with a 50 kg load cell and a 38 mm diameter acrylic cylinder probe. Texture profiling involved compressing the test substance at least twice and quantifying the mechanical texture parameters from the recorded force-deformation curves. These included; hardness (N), cohesiveness, adhesiveness, springiness (%), chewiness (N) and resilience. The instrument settings were: pre-test speed 1.0 mm/s; test speed 5.0 mm/s; post-test speed 5.0 mm/s; 30 % compression, trigger type auto force 5 g and data acquisition rate 200 pps. The waiting time between the first and second compression cycle was 5 s.

Results and Discussion

Hardness and firmness of dried and dried-rehydrated beef samples. The mean values of hardness (N) of solar dried and open sun dried beef samples as measured by puncture test (x 101) and texture profile analysis are given in Figure 1. The firmness results (N) as given by the volodkevich method are also shown. The instrumental texture parameters of hardness/ firmness/softness measure the scale of resistance of food to applied compressive forces. The textural properties of hardness and firmness of foods are closely related and the boundaries between them instrumentally are not yet known (Szczesniak, 2002). The hardness values of the solar dried slices obtained for the puncture test and texture profile analysis ranged from 3.50±0.11 to 4.47±0.07 and 25.08±4.99 to 33.04±5.73 N, respectively, while the firmness values of the volodkevich bite jaws test ranged from 32.93±1.81 to 46.60±0.99 N.

The puncture test hardness values were significantly lower ($P \leq 0.05$) than the values found for all the test methods used and were approximately ten times lower than the volodkevich firmness values. This could be explained by the fact that the puncture test was used to assess the crust penetration force and inner tissue firmness of the dried product; whereas the

TPA and volodkevich imitative tests were used to determine resistance to the compressing forces (Szczesniak, 2002). The TPA test could only be done on rehydrated samples resulting in a lower force of compression compared to the force required to deform samples for the volodkevich test. However, there was a high level of variability of the results as given by the large values of standard deviation of the TPA samples. This could have been caused by the irregular structure of the samples as a result of shrinkage even after 20 min of rehydration. De Huidobro *et al.* (2005) compared the Warner-Bratzler shear test and TPA method to determine the sensory characteristics associated with the texture of fresh beef and indicated that the TPA test predicted the sensory hardness better than the Warner-Bratzler test. According to Saláková (2012), TPA tests need to be performed on samples with a smooth flat surface so that the area in contact with the plate is known and constant.

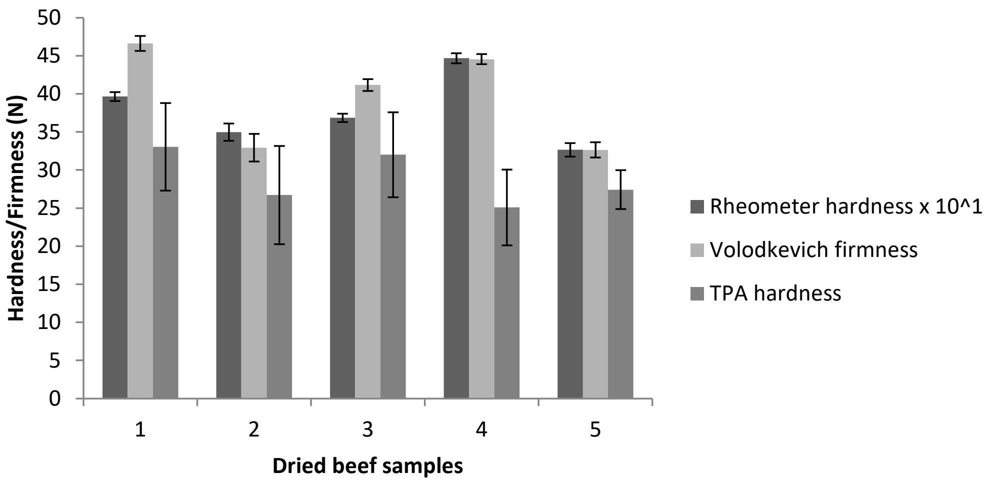

Figure 1. Comparison of hardness and firmness of beef using three instrumental methods

The sample numbers 1-4 represent samples dried in the different sections of the solar dryer (A-D) respectively, while sample 5 represents sundried beef samples. Each value is expressed as mean ± standard deviation (n=3).

The texture values (rheometer hardness and volodkevich firmness) of the sun dried beef were significantly lower ($P \leq 0.05$) than that of solar dried beef samples, particularly for samples at the extreme ends of the solar tunnel dryer (sample A and D). When drying was performed at higher temperatures, a substantial increase in force for puncturing or compressing beef slices was observed, possibly due to the formation of an intensive crust layer on the surface. This toughness was primarily due to aggregation of muscle protein, especially actomyosin, by crosslinking (Byrde and Sands, 1981). The high moisture content of the sun dried beef could also have resulted in more tender meat. Youssef *et al.* (2007) related the moisture content with shear values, and observed that the higher the moisture content the more the tenderness of charqui meat. The authors indicated that moisture content was the primary cause of charqui meat texture. There was no significant difference ($P > 0.05$) in texture of rehydrated beef samples analysed by TPA, which could be attributed to the higher rehydration ratio of the solar dried samples.

Other texture profile analysis (TPA) parameters. Table 1 gives other instrumental texture profile analysis parameters for rehydrated sun and solar dried beef samples. The classification of textural terms for solids and semi-solids give rise to a profiling method of texture description, TPA, applicable to both sensory and instrumental measurements. The adhesiveness of sun dried beef had an average value of -1.68±0.03 while solar dried beef samples had adhesiveness values of 0.00±0.00. Adhesiveness is normally given with a negative value and it describes the work necessary to overcome the attractive forces between the surface of the food and the surface of the other materials with which the food comes in contact (Szczesniak, 2002). The adhesiveness of sun dried beef could be attributed to the higher moisture content of the samples.

Table 1. Effect of drying methods on other texture profile analysis parameters of dried rehydrated beef samples

	Texture parameter				
Samples	Adhesiveness	Springiness	Cohesiveness	Chewiness	Resilience
Solar dried					
A	0.00±0.00[b]	2.91±3.19[b]	0.88±0.01[a]	90.38±129.51[a]	0.79±0.13[b]
B	0.00±0.00[b]	0.90±0.06[ab]	0.84±0.04[a]	35.98±30.98[a]	0.65±0.14[ab]
C	0.00±0.00[b]	1.08±0.88[ab]	0.84±0.02[a]	12.10±1.59[a]	0.65±0.04[ab]
D	0.00±0.00[b]	0.95±0.08[ab]	0.85±0.01[a]	53.10±20.81[a]	0.74±0.07[ab]
Sun dried	-1.68±0.03[a]	0.25±0.32[a]	0.81±0.19[a]	7.21±7.91[a]	0.63±0.03[a]

Means in the same column with the same superscripts are not significantly different at P > 0.05.

Springiness and resilience values of sun dried beef were significantly ($P \leq 0.05$) lower compared to the solar dried samples. This could be attributed to the higher moisture content of the sun dried samples. Springiness can be related to how the food structure breaks during chewing. The meat structure in samples displaying high springiness values showed a better recovery and did not break or change as much during compression as samples with lower values. Similar results on effect of moisture content on springiness of meat samples have been reported by Martinez *et al.* (2004) whereby springiness decreases with increase in moisture content. There was no significant difference between the cohesiveness and chewiness of the solar and sun dried beef samples.

Conclusions

The rheometer puncture test and volodkevich bite jaws test methods can predict the instrumental hardness and firmness texture properties of sun and solar dried beef samples better than the TPA test method. In terms of textural parameters of dried beef, solar dried beef samples have higher hardness (N), firmness (N), springiness (%) and resilience and lower adhesiveness compared to sun dried beef samples.

Acknowledgement

The financial support from the German Federal Ministry of Education and Research (BMBF), in the framework of the project 'Reducing Losses Adding Value-RELOAD' is greatly acknowledged by the authors of this paper. This paper is a contribution to the 2018 Sixth African Higher Education Week and RUFORUM Biennial Conference.

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