AVANCES
EN CIENCIAS E INGENIERÍAS
ARTÍCULO/ARTICLE
SECCIÓN/SECTION C

Effect of drying time and different beef muscles cuts on physicochemical and sensory characteristics of dried meat (Jerky)

Lucía Ramírez-Cárdenas[1*]

[1] *Universidad San Francisco de Quito, Colegio de Ciencias e Ingenierías - El Politécnico, Calle Diego de Robles y Vía Interoceánica, Cumbayá, Casilla Postal: 17-1200-841,Quito-Ecuador.*
[*] *Autor principal/Corresponding author, e-mail: lramirez@usfq.edu.ec*

Editado por/Edited by: Cesar Zambrano, Ph.D.
Recibido/Received: 2015/03/03. Aceptado/Accepted: 2015/04/29.
Publicado en línea/Published online: 2015/05/22. Impreso/Printed: 2015/06/01.

Abstract

Meat products have a broad market in Ecuador; however, jerky (dry meat) is rarely known and there are no products preserved using osmotic dehydration (OD). OD improves organoleptic characteristics of meat, thus it allows to use less economically valued meat cuts. The objective of this work was to evaluate the effect of drying time on three beef cuts, regarding the physicochemical characteristics (Moisture Content, Moisture:Protein Relation, MPR, and Water Activity A_a) and sensory characteristics in the elaboration of jerky that was previously dehydrated by OD, employing a 60°Brix hypertonic solution. OD procedure was considered to be finished when a moisture content of 55g/100g of product was achieved for all treatments. During the air drying stage, a Completely Randomized Design (CRD) with factorial arrangement 3^2 was used (Time: 4h, 5h, and 6h and muscle cut: *Infraspinatus*, *Rectus femoris*, *Pectoralis profundus*) at constant temperature (68.5°C). Five hours drying time treatments (T2, T5 and T8) presented better results for all three muscles types on physicochemical characterization and were evaluated by 65 consumer panelists through a preference test, in which no significant difference among treatments was observed. *Pectoralis profundus* is considered to have lesser market value compared to the other two muscles, hence its use for this type of products is highly recommended.

Keywords. Jerky, *Infraspinatus*, *Rectus femoris*, *Pectoralis profundus*, Moisture Protein Ratio, Osmotic Dehydration.

Efecto del tiempo de secado y de distintos cortes de músculos de res en las características fisicoquímicas y sensoriales de carne seca (cecina)

Resumen

Pese al gran posicionamiento que tienen los productos cárnicos en el Ecuador, el Charqui (carne seca) es poco conocido y no existen productos conservados usando deshidratación osmótica (DO). La DO mejora las características organolépticas de la carne por lo que permite utilizar cortes de menor costo económico. El objetivo de este trabajo fue evaluar el efecto de diferentes tiempos de secado en tres tipos de músculo de res sobre las características fisicoquímicas (contenido de Humedad, Relación Humedad: Proteína MPR, y Actividad de Agua A_a) y organolépticas en la preparación de Charqui, previamente deshidratado mediante DO utilizando una solución hipertónica 60°Brix. La DO se consideró terminada para los tratamientos al alcanzar un contenido de Humedad de 55g/100g de producto. Para la etapa de secado se utilizó un diseño completamente al azar (DCA) con arreglo factorial 3^2, correspondiente a 2 factores (Tiempo: 4h, 5h, y 6h y tipo de músculo: *Infraspinatus*, *Rectus femoris*, *Pectoralis profundus*) a temperatura constante (68.5°C). Los tratamientos de 5 horas de secado para todos los músculos (T2, T5 y T8) presentaron los mejores resultados en la caracterización físico-química y al ser evaluados sensorialmente por 65 consumidores a través de una prueba de preferencia no presentaron diferencia significativa. *Pectoralis profundus* es un músculo con un valor en el mercado considerablemente menor a los dos anteriores, por lo que su utilización puede ser altamente recomendada en este tipo de productos.

Palabras Clave. Charqui, *Infraspinatus*, *Rectus femoris*, *Pectoralis profundus*, Relación Humedad:Proteína, Deshidratación osmótica.

Introduction

Meat products have a broad market in Ecuador, for consumers as well as producers. Data reported by the Ecuadorian Institute of Statistics and Census (INEC) [1] shows that 5.3 million heads of cattle are reared across the country every year. As for consumption, an average person eats 13.8 kg of meat annually, which is used as a source of protein in a 42.5%, 32.0% y 31.7% in high,

ISSN 1390-5384

middle and low social class respectively. To satisfy this demand, several techniques have been employed to increase product's shelf-life. The currently available products in the Ecuadorian market are mostly cold, cured or canned meat; but there are no products preserved by osmotic dehydration.

Osmotic dehydration (OD) is a food preservation method that eliminates water held in the interior of cellular solids. It is done by immersion of the product in a hypertonic solution, forming an osmotic pressure gradient because of the difference of concentrations between them. As a result, three main mass transfers occur in this process: (1) water flow from the product to the solution, (2) solutes are transferred from the solution to the product and (3) a loss of the product's own solutes into de hypertonic solution (Lück, 1995; Pezo et al., 2013). Energy savings and waste reduction are the main advantages of OD compared to other drying techniques.

Filipovic et al. [2] highlighted the importance of using ternary solutions (two solutes and one solvent) during de OD process in meat products, since they speed up the process. The combination of a salt along with a compound of larger molecular weight, such as sucrose or another sugar, increases the osmotic pressure gradient [3]. This also has a quality implication because it reduces salt impregnation in the product; thus improving organoleptic and nutritional characteristic [4, 5].

Different meat proteins play an important role on water retention inside de muscular tissue. Water is the major component in beef, being around the 75% of its total weight, and it is held inside muscular fibers in three different forms: (1) a first layer of *bond water* that interacts with charged functional groups of proteins and is resistant to evaporation; (2) a layer of *non-mobile* water that is attracted by esteric effects to bond water and that gradually turns into a (3) layer of *free water* [6, 7]. Regions (1) and (2) hold from 20% up to 27% of the total amount of water found in beef [8, 9].

Dried meat is one of the oldest preserved foods known by men. It is relatively easy to process and it does not need refrigeration during its commercial distribution due to its low water activity (A_w) [10]. Jerky is a marinated and dried meat, which can be made with whole or minced meat. The United States Department of Agriculture (USDA) defines jerky as a "meat product ready to eat that has been heat-treated and has a prolonged shelf-life" [11].

Jerky processing normally consist in a marinating stage followed by a drying treatment generated by circulation of hot air over the product, which is kept in trays, in order to eliminate water using convection [12]. Drying is necessary to reduce water activity, inactivate enzymes and to decrease microbial content [12, 13]. The absence of *Escherichia coli* O158:H7, *Listeria monocytogenes* and *Salmonella* must be guaranteed throughout a heat-treatment that reaches a minimal internal temperature of 71.1°C in the middle of the product [11, 14]. The USDA established a maximum A_w of 0.85, and a Moisture-Protein Ratio (MPR) equal or less than 0.75:1 to assure shelf life stability of beef jerky.

Processing conditions and the properties of the meat employed, affect the characteristics of the final product, as well as the efficiency of its elaboration. Miller et al. [15] revealed that jerky produced with heart muscle had more protein and was less prone to nutrient loss in comparison to tongue and round top muscles in beef. However, this investigation did not specify any result regarding water activity, nor it reported water holding capacity changes of the studied muscles. Rahman et al. [16] conducted an investigation of the physical-chemical properties of jerky using goat meat and different drying methods. They concluded that drying methods affect quality attributes. Mamani-Linares and Cayo [17] determined some physical-chemical properties of jerky made with llama, horse and beef, showing that beef jerky had less water content, water activity and fat; thus it is highly recommended for these products.

Given the importance and world development of osmotic dehydration as a preservation technique, several studies have been made in order to optimize the process of meat products. Previous works have focused on different processing conditions during beef dehydration, as well as the concentration of the hypertonic solution employed, temperatures, time and final moisture reached [18–20]. On the other hand, packaging and storage procedures, such as modified atmospheres, have been developed [21]. Still, few studies have been carried out regarding beef cuts and its possible influence in osmotic dehydration, and moreover in the physicochemical and sensory characteristics of the final product.

It is well known that OD improves color and flavor characteristics in meat products [19]; hence it can increase the sensory attributes of low rated value beef cuts. It is necessary to find a muscle cut that allows an optimum processing method and also that is accepted by consumers. The market value of different beef cuts depends, in great measure, of its tenderness. Calkins and Sullivan [22] classified beef muscles according to their tenderness (tough, intermediate, tender) measured by resistance to shear force. The variation of this resistance between different muscles is due mainly because of the concentration and characteristics of the connective tissue involved [9]. In the present investigation three cuts with different tenderness rankings were chosen: *Infraspinatus* (tender), *Rectus femoris* (intermediate), and *Pectoralis profundi* (tough). Sensory perception of the consumer and its differentiation ability among different tenderness rankings in processed meat products, such as jerky, can have a number of practical implications.

In Ecuador there are no products similar to jerky, excluding minor importations of selected stores at high prices. The main objective of this work was to evaluate the effect of different processing times in three different beef muscles in the elaboration of dried meat (jerky),

Variable	Initials	Method	Specification
Water Activity	A_a	Official method AOAC 978.18	<0.85
Moisture Protein Ratio	MPR	Official method AOAC 2001.11 and Official method AOAC 960.39	<0.75
Moisture Content	Mc	Official method AOAC 960.39	<21g/100g

Table 1: Response Variables, methods and specifications.

Muscle	Expressible moisture [31]	Final moisture content at 12 hours (g/100g)
Rectus femoris	40.33	51.28
Pectoralis profundus	39.02	52.90
Infraspinatus	38.48	53.97

Table 2: Expressible moisture and final moisture content for each muscle.

through the determination of water content, MPR, A_w and sensory evaluation.

Materials and Methods

Raw Material

Three different beef muscle cuts were used according to the Institutional Meat Purchase Specifications [23]: *Infraspinatus* Shoulder Clod-114D (INF); *Rectus femoris* Round Knuckle Tip 167E (REF); *Pectoralis profundus* Boneless Brisket 120 (PEP).

Osmotic Dehydration

Previous Tests

In order to calculate proper amount of the required solutes in the hypertonic solution, this study used four 60° Brix solutions with different sodium chloride (NaCl) and sucrose ($C_{12}H_{22}O_{12}$) relations. Colato et al. [3] recommended hypertonic solutions that have $C_{12}H_{22}O_{12}$ concentrations ranking from 40 to 70%, and from 5 to 20% for NaCl. Outside these ranges the flavor of the product is negatively affected. The four combinations were: 9%NaCl-51%$C_{12}H_{22}O_{12}$, 11%NaCl-49%$C_{12}H_{22}O_{12}$, 13%NaCl-47%$C_{12}H_{22}O_{12}$, 15%NaCl-45%$C_{12}H_{22}O_{12}$.

Each one of these solutions was placed inside ZipLock® bags along with 300g of meat cut in cubes of 1.5cm per side made from PEP muscle. The solution:meat relation was 5:1 w/w [19–21]. OD was conducted at 4°C [11, 14, 24] for 12 hours in order to determine the amount of time needed to achieve a moisture content of 55g/100g of product established by Pezo et al. [20]. Moisture content was determined by duplicate every 2 hours according to AOAC method 934.01 [25]. The best combination was selected based on: (1) final moisture reached and (2) a six people *focus group* that tasted and evaluated each sample to define proper salt concentration.

Characterization of the Osmotic Dehydration Curve

The chosen NaCl-$C_{12}H_{22}O_{12}$ combination was prepared dissolving 110g of NaCl and 490g of $C_{12}H_{22}O_{12}$ for every 400g of water. Processing of the three types of muscles for OD was made in the same way described in the previous tests and using same temperature. Moisture content was determined by triplicate every hour during 12 hours [25]. A dehydration curve (moisture content vs. time) was made for each muscle with the results obtained in this procedure. The required time to achieve the desired moisture content (55g per 100g of product) was calculated by interpolation of data found in each dehydration curves.

Marinating and Drying

Meat cubes were marinated in a 30°Brix sauce (containing powdered garlic, soy sauce, teriyaki sauce, mustard, powdered pepper, oregano, and sesame seed oil) with a meat:sauce relation 1:0.5 w/w in a Tumbler (Rühle M130) at -2°C for 40 minutes with vacuum (-0.90 bar) and a tank position number 2 without stirring arm (using program 25 which is specific for jerky and beef strips in this equipment). Samples were dried in a Precision (Economy Oven 45EG) at 68.5°C according to times set in the experimental design. A heat treatment, described by Nummer et al. [11], at 135°C for 10 minutes was made.

Experimental Design

A Completely Randomized Design (CRD) with factorial arrangement 3^2 was employed (combination of 2 factors with 3 levels each: type of muscle used (INF, REF, PEP) and drying time (4, 5 and 6 hours). Muscle types were chosen according to their tenderness ranking described by Calkins and Sullivan [22], and drying times were determined according to Nummer et al. [11]. Three repetitions were done, obtaining a total of 27 experimental units. Response variables with their respective specifications are described in Table 1.

The data were subjected to analysis of variance (ANOVA) and means were assessed by Tukey test ($P<0.05$).

Pondering Table

Water activity of jerky has been described by several researchers [11, 14, 24] as the main variable for microbiological control (valuation 3); followed by MPR (<0.75) (valuation 2) required to categorize a product as jerky. According to the USDA [11], moisture content does not

Source of Variation	d.f.	Mean Squares		
		A_w	MPR	Moisture content (g/100g)
Treatments	8	$2.03x10^{-3n.s.}$	$1.12x10^{-2}$*	14.8*
Factor A (Muscle)	2	$9.92x10^{-4n.s.}$	$6.44x10^{-4n.s.}$	$2.26^{n.s.}$
Factor B (Time)	2	$6.18x10^{-3}$*	$3.20x10^{-4}$*	43.7*
Interaction AxB	4	$4.83x10^{-4n.s.}$	$6.16x10^{-3}$*	6.60*
Experimental Error	18	$8.48x10^{-4}$	$1.72x10^{-3}$	1.14
Total	26	$1.21x10^{-3}$	$4.64x10^{-3}$	5.34

*: significant at 5% probability by F test.
$^{n.s.}$: not significant at 5% probability by F test.

Table 3: Summary of the analysis of variance (ANOVA) for A_w, MPR and Moisture Content of treatments.

guarantee product's safety, which is why this is the least important variable (valuation 1). However, Allen et al. [26] recommended moisture analysis to have a better understanding of the shelf life of the product, and Lim et al. [27] highlighted the importance of moisture content in jerky's texture.

Sensory Evaluation

A preference test was done by 65 consumer type judges [28], all students from San Francisco de Quito University between 17 and 24 years old; 36 women (55.39%) and 29 men (44.61%). Treatments were coded using three randomized numbers. Jerky samples were presented simultaneously in meat cubes of 1.2cm per side (3g each). In the form given judges were asked to try samples from left to right and order them according to their preference, being 1 "most preferred" and 3 "less preferred" [29]. They were asked to drink water and wait thirty seconds between each sample [29]. Friedman's test was employed using Chi-square equation to determine statistical differences. X^2 value was obtained according to Equation 1, and compared to the value given in the Chi-square distribution table (G.L. = 2 and 5% probability) [29], according to the same equation:

$$X^2 = \frac{12}{N \cdot k\,(k+1)} \sum_{j=1}^{k} (R_j)^2 - 3N\,(k+1) \qquad (1)$$

Where, N = number of judges
K = number of samples
R = summation of each treatment

Results y Discussion

Osmotic Dehydration

Graphic 1 shows the osmotic dehydration curves for the four different combinations of NaCl:$C_{12}H_{22}O_{12}$ for meat cubes (1.5cm per side) of PEP muscle. The sample that contained the highest NaCl concentration dehydrated slightly better than the rest, reaching a final moisture content of 51.24g/100g after 12 hours of treatment, whereas the sample that only contained 9% NaCl only reached a moisture content of 55.91g/100g in the same time. Sucrose usage increases solution viscosity, leading to inhibition of mass transfer due to formation of a sugar barrier in the product's surface [5, 30]. The difference between the 9% NaCl sample with the rest may be caused by this phenomenon. NaCl reduces water activity more efficiently, but its concentration in hypertonic solutions is restricted for giving an excessive salty taste in the product [5]. Given that the last three combinations dehydrated the meat in similar ways, the solution containing 11%NaCl-49%$C_{12}H_{22}O_{12}$ was chosen for organoleptic reasons.

Dehydration curves for each muscle are presented in Graphic 2. Time 0 of the curve represents the initial moisture content for all muscles. All samples had higher values than those reported by Von Seggern et al. [31]. However, a similar tendency was maintained where INF had the lowest moisture value in comparison with the two other muscles. Initial moisture content can be affected by several factors such as age, gender and animal rearing [9].

When osmotic dehydration began, some similarities appeared for the three muscle types: during the five first hours of dehydration there was a quick moisture drop in the product. This occurred, as expected, given that existed a wider gradient of osmotic pressure [3, 5]. Then, dehydration speed in meat cubes diminished considerably, keeping a moisture of 60g/100g until the 8^{th} hour. It seems that NaCl was responsible for the first quick dehydration moment given its capability to penetrate cell membranes. Colato et al. [3] presented similar results with the same 11% NaCl content in different food products.

The required times to achieve the established moisture content of 55g/100g were 11.52h, 10.28h and 11.30h for INF, REF and PEP, respectively. REF was the muscle which eliminated water faster than INF and PEP, and this may be due to its *free water* content [32]. Using centrifugation methods it is possible to calculate the amount of *drip loss* and retained water in meat proteins [7]. Drip loss comes from *expressible moisture* and it gives a close idea of the total amount of free water in a sample. Von Seggern et al. [31] reported values of expressible moisture for several muscles, where REF had a higher value than INF and PEP. Table 2 shows the amount of expressible moisture and the final moisture content reached after 12 hours of OD for each muscle.

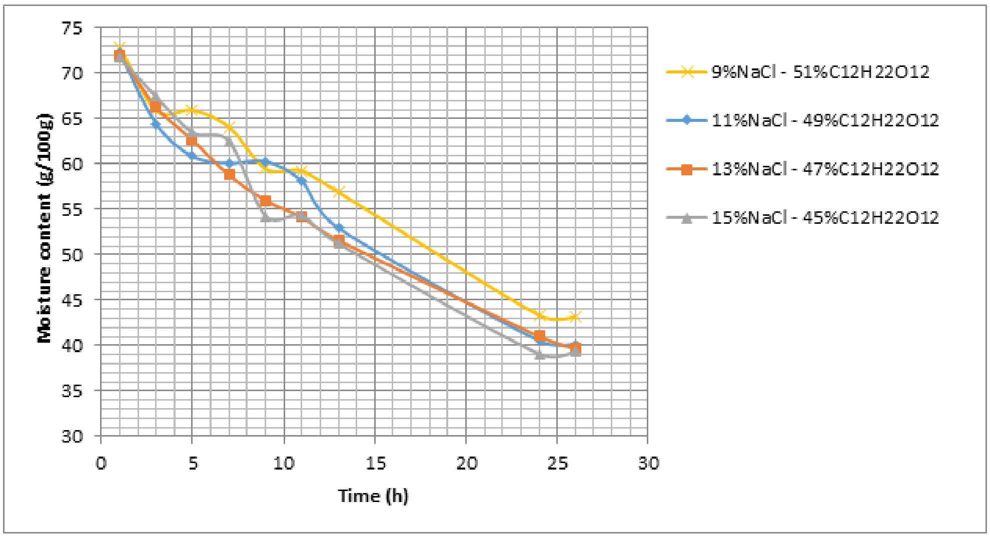

Figure 1: Osmotic dehydration curves for four different combinations of NaCl:$C_{12}H_{22}O_{12}$ for meat cubes (1.5cm per side) of PEP muscle.

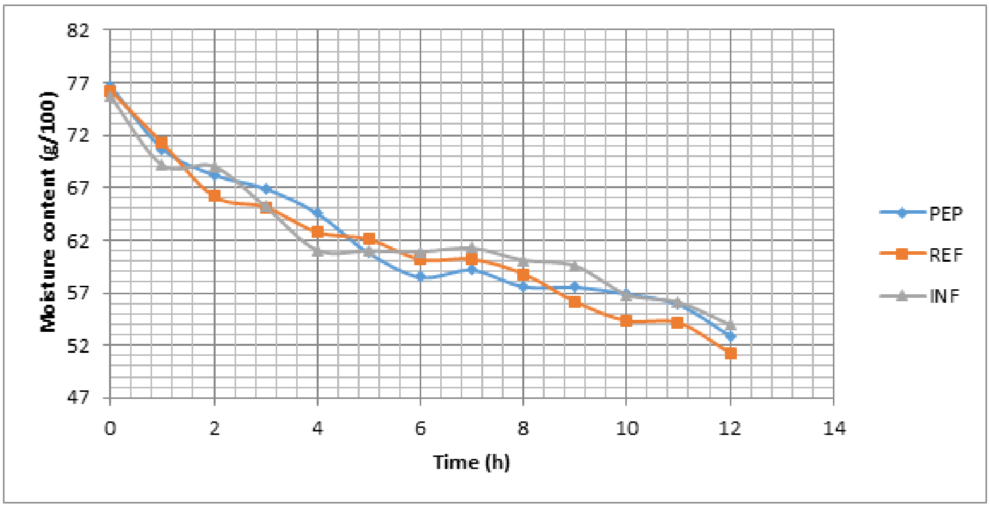

Figure 2: Osmotic Dehydration for each different muscle (PEP, REF, INF).

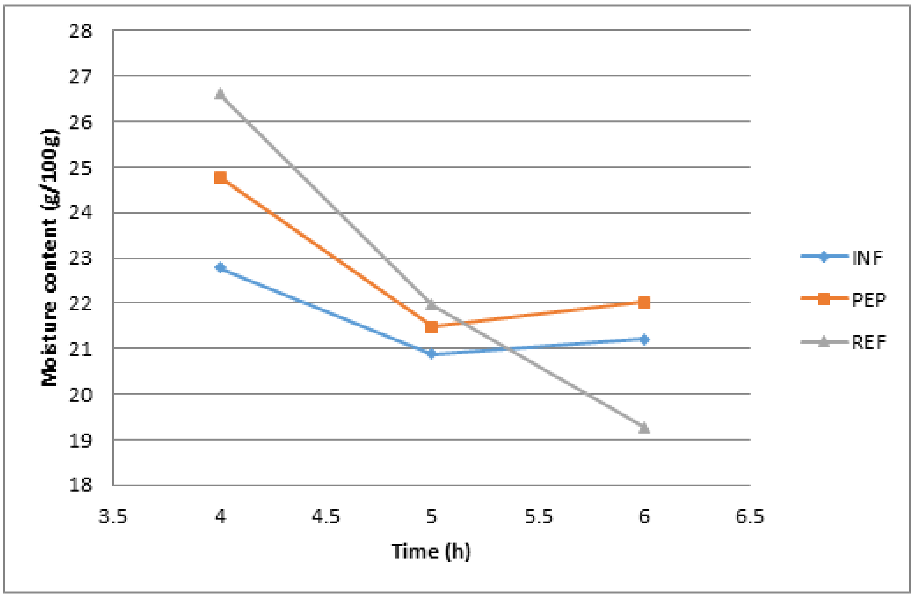

Figure 3: Drying procedure for the three muscle cuts at 4, 5 and 6 hours.

Treatments	A_a*
T7	0.628 ± 0.019
T1	0.613 ± 0.045
T4	0.608 ± 0.012
T6	0.588 ± 0.033
T5	0.583 ± 0.009
T8	0.582 ± 0.007
T9	0.565 ± 0.027
T2	0.556 ± 0.042
T3	0.553 ± 0.038

* Values are mean ± SD

Table 4: A_w of treatments

Awis et al. [6] investigated the water holding capacity of 9 different muscles, finding that INF had less drip loss than REF, although in this study PEP muscle was not analyzed.

Drying Procedure

Table 3 presents the summary of analysis of variance (ANOVA) of the physicochemical characterization of the treatments. Significant differences existed within treatment regarding MPR and moisture content, but not for A_w. The type of muscle used did not influenced in any of the variables analyzed, whereas drying time was very important. Factor interaction (Muscle and Time) influenced in MPR and moisture content, but not for A_w.

Water Activity (A_w)

There was no statistical difference between treatments (Table 3). All treatments achieved established A_w parameter <0.85 (Table 4) for jerky commercialization [22]. Furthermore, all treatments had an A_w lower than 0.70, which according to Nummer et al. [11] and Rodríguez [33] is a control method for jerky that has not employed yeast and mold inhibitors. Boles et al. [14] presented similar $A_w$results for this product. The low A_w of treatments revealed the influence of OD in drying time; Bowser et al. [10] reported drying times longer than 6 hours by traditional methods at the same temperature, and Lim et al. [26] required 8 hours at 70°C.

It would be logical to suppose shorter drying times with the A_w given to reduce energetic costs. Nevertheless, some researchers [11, 34] have stated that the minimum time required at 68.5°C to assure the products microbiological safety and absence of *E. coli 0157:*H7, *Listeria mococytogenes* and *S. aureus* is 4 hours.

Moisture Protein Ratio (MPR)

All the nine treatments reached established MPR for jerky (<0.75) [23]. Table 5 shows that the only muscle that has statistical difference between 4 hours and 6 hours of treatment was REF. On the other hand, the coefficient of variation for MPR (CV= 8.48%) was higher in comparison with A_w (CV= 4.97%) and moisture content (CV=6.00%). This could be explained because MPR is obtained from two values, the mathematical relation between moisture and protein. Allen et al. [25] and Rodríguez [33] reported similar values for these variables in other jerky studies.

Treatments	MPR*
T7	0.597 ± 0.049^{a}
T4	0.565 ± 0.060^{ab}
T1	0.508 ± 0.030^{abc}
T3	0.487 ± 0.028^{abc}
T5	0.472 ± 0.002^{bc}
T8	0.470 ± 0.077^{bc}
T6	0.456 ± 0.040^{bc}
T2	0.447 ± 0.015^{bc}
T9	0.396 ± 0.013^{c}

* Values are mean ± SD
*Means followed by the same letter are not significantly different at 5% probability by Tukey Test.

Table 5: Moisture Protein Ratio (MPR) of treatments.

Moisture Content

Some investigators [6, 7] concluded that speed and dehydration capacity in meat products depend on the amount of *bound* and *non-mobile water*. Once free water is eliminated from the product, evaporation speed is considerably reduced. This can be observed in Graphic 3, where INF and PEP treatments kept their moisture close to 20g/100g from the fifth hour on, but REF reached 18g/100g after 6 hours. Price and Schweigert [8] established a 20% *bound* and *non-mobile* water for most beef cuts. The continued moisture evaporation in REF might be explained because of its *expressible water* content. All treatments of four drying hours (T7, T4 y T1) did not achieved the maximum established parameter for moisture content (<21g/100g) (Table 6).

Pondering of Variables

Treatments of five and six drying hours for all muscles had the higher score values (Table 7). Treatments of five hours for all muscles were chosen for sensory evaluation because of less energetic costs (T2, T5 and T8).

Treatments	Mc(g/100g)*
T7	26.115 ± 0.660^{a}
T4	24.265 ± 0.912^{ab}
T1	22.272 ± 0.972^{bc}
T5	20.988 ± 0.828^{cd}
T8	20.933 ± 2.014^{cd}
T6	20.858 ± 0.783^{cd}
T3	20.720 ± 0.229^{cd}
T2	20.383 ± 0.276^{cd}
T9	18.779 ± 1.588^{d}

* Values are mean ± SD
*Means followed by the same letter are not significantly different at 5% probability by Tukey Test.

Table 6: Moisture content of treatments.

Sensory Evaluation

The calculated X^2 value was 0.369, significantly inferior to the critical value of 5.991, therefore there was no significant difference between treatments. Consumers did not show any preference for a particular sample, and any of the muscles cuts studied could be employed for future marketing tests. It could have been expected that consumers reject PEP samples because of more intercrossed bonds in their connective tissue, which increases meat hardness [9]. Given that PEP is a low valued market meat cut with low prices, it should be the muscle with more commercial interest in jerky products.

Acknowledgements

The authors will like to the Department of Food Engineering from Universidad San Francisco de Quito for the resources provided, as well as its personnel for all the support given to fulfill this project.

References

[1] INEC. 2011. "Censo Agropecuario". *Link: www.inec.gov.ec. Instituto Nacional de Estadísticas y Censos: Ecuador*.

[2] Filipović, V.; Levic, L.; Ćurčić, B.; Nićetin, M.; Pezo, L.; Mišljenović, N. 2014. "Optimization of mass transfer kinetics during osmotic dehydration of pork meat cubes in complex osmotic solution". *Chemical Engenieers of Serbia*, 20(3):305–314.

[3] Colato Antonio, G.; Moreira Azoubel, P.; Xidieh Murr, F.; Jin Park, K. 2008. "Osmotic dehydration of sweet potato (*Ipomoea batatas*) in ternary solutions". *Ciência e Tecnologia de Alimentos*, 28(3):696–701.

[4] Bohuon, P.; Collignan, A.; Rios, G.; Raoult-Wack, A. 1998. "Soaking process in ternary liquids: experimental study of mass transport under natural and forced convection". *Journal of Food Engineering*, 37(4):451–469.

[5] Tortoe, C. 2010. "A review of osmodehydration for food industry". *African Journal of Food Science*, 4(6):303–324.

[6] Awis Qurni, S.; Mohamad Abdullah, H.; Taiwo Olusesan, A.; Jothi Malar, P. 2011. "The effects of carcass conditioning on shear force values and water holding capacity of different skeletal muscles of Malaysian Indigeneous (Malin) sheep and the changes in their pH and glycogen contents". *Journal of Animal and Veterinary Advances*, 10(23):3100–3106.

[7] Kerth, C. 2013. "The Science of Meat Quality". *Acribia, S.A.: Zaragoza España*.

[8] Price, J.; Schweigert, B. 1987. "The science of meat and meat products". *Food and Nutrition Press: Connecticut*.

[9] Lawrie, R. 1998. "Ciencia de la Carne". *Acribia, S.A.: Zaragoza, España*.

[10] Bowser, T.; Frazier, S.; Weckler, P.; Kowalski, S. 2009. "Optimizing Jerky Drying Time with Minimal Product Impact". *The Open Food Science Journal*, 3:79–83.

[11] Nummer, B.; Harrison, J.; Harrison, M.; Kendall, P.; Sofos, J.; Andress, E. 2004. "Effects of Preparation Methods on the Microbiological Safety of Home-Dried Meat Jerky". *Journal of Food Protection*, 67(10):2337–2341.

[12] Clemente, G. 2003. "Efecto de la contracción en la cinética de secado de músculos de jamón". *Tesis de doctorado, Universidad Politécnica, Valencia, España*.

[13] Chirinos Michilo, V.; Ortiz Zevallos, N. 2010. "Secado de carne: Influencia del tiempo y temperatura de secado en la pérdida de agua". *Tesis de ingeniería, Universidad Wiener, Lima, Perú*.

[14] Boles, J.; Neary, K.; Clawson, K. 2014. "New interventions and validation for the control of pathogens in the processing of jerky". *Food Safety and Inspection Service, USDA. http://www.fsis.usda.gov*.

[15] Miller, M.; Keeton, J.; Cross, H.; Leu, R.; Gomez, F.; Wilson, J. 2007. "Evaluation of the physical and sensory properties of jerky processed from beef hear and tongue". *Journal of Food Quality*, 11(1):63–70.

[16] Rahman, M.; Salman, Z.; Isam, T.; I., K.; Mothershaw, A.; Al-Riziqi, M.; Guizani, N.; Mahgoub, O.; Ali, A. 2005. "Microbial and physic-chemical characteristics of dried meat processed by different methods". *International Journal of Food Engineering*, 1:8–16.

[17] Mamani-Linares, W.; Cayo, F. 2011. "Características fisicoquímicas de charqui bovino, llama y equino". *Revista de Investigaciones Veterinarias del Perú*, 22:290–300.

[18] Agustinelli, S.; Salvador, V.; Yeannes, M. 2013. "Determination of the moisture sorption behavior of osmotically dehydrated mackerel fillets by means of binary and ternary solutions". *Food Science and Technology International*, 20(5):353–363.

[19] Filipović, V.; Ćurčić, B.; Nićetin, M.; Plavšić, D.; Koprivica, G.; Mišljenović, N. 2013. "Mass transfer and microbiological profile of pork meat dehydrated in two different osmotic solutions". *Hemijska Industrija*, 66(5): 743–748.

[20] Pezo, L.; Ćurčić, B.; Filipović, S.; R., M.; Nićetin, G.; Koprivica, B.; Nevena, M.; Mišljenović, L.; Lević, B. 2013. "Artificial neural network model of pork meat cubes osmotic dehydration". *Hemijska Industrija*, 67: 465–475.

[21] Suput, D.; Lazić, L.; Pezo, L.; Lević, L.; Gubić, J.; Hromiš, N.; Sojić, B. 2013. "Modified atmosphere packaging and osmotic dehydration effect on pork quality and stability". *Romanian Biotechnological Letters*, 18(2):8160–8169.

[22] Calkins, C.; Sullivan, G. 2007. "Ranking of Beef Muscles for Tenderness". *Universidad de Nebraska*: 1–5.

[23] NAMP. 2007. "The Meat Buyers Guide". *North American Meat Processors Association, Reston: Virginia*: 1–22.

[24] Garcia, L. 2009. "Functional properties and utilization of high pH beef". *Tesis de doctorado. Universidad Texas A&M: Texas, Estados Unidos.*

[25] A.O.A.C. 2004. "Official methods of Analysis of A.O.A.C International: Food Composition, Additives, Natural Contaminants". *Gaithersburg: Maryland, EE.UU.*

[26] Allen, K.; Cornforth, D.; Whittier, D.; Vasavada, M.; Nummer, B. 2007. "Evaluation of High Mcidity and Wet Marinade Methods for Pasteurization of Jerky". *Journal of Food Science*, 72(7):351–355.

[27] Lim, H.; Kim, G.; Jung, E.; Seo, H.; Joo, S.; Jin, S.; Yang, H. 2014. "Effect of curing time on the physicochemical and sensory properties of beef jerky replaced salt with soy sauce, red pepper paste and soybean paste". *Asian-Australas Journal Animal Science*, 27(8):1174–1180.

[28] Wittig de Penna, E. 2001. "Evaluación Sensorial. Una metodología actual para tecnología de alimentos". *Biblioteca Digital de la Universidad de Chile*.

[29] Ramírez-Navas, J. 2012. "Análisis sensorial: pruebas orientadas al consumidor". *Revisiones de la ciencia, tecnología e ingeniería de alimentos*, 12:83–97.

[30] Mastrantonio, S.; Pereira, L.; Hubinger, M. 2005. "Osmotic dehydration kinetics of guavas in maltose solution with calcium salt". *Alimentos y nutrición Araraquara*, 16(4):309–314.

[31] Von Seggern, D.; Calkins, C.; Johnson, D.; Brickler, J.; Gwartney, B. 2005. "Muscle profiling: Characterizing the muscles of the beef chuck and round". *Meat Science*, 71:39–51.

[32] Simal, S.; Femenia, A.; Garcia-Pascual, P.; Rossello, C. 2003. "Simulation of the drying curves of a meat-based product: effect of the external resistance to mass transfer". *Journal of Food Engineering*, 58:193–199.

[33] Rodríguez Soto, S. 2011. "Evaluación de dos músculos de res y dos tratamientos térmicos en las características de jerky". *Tesis de licenciatura. Universidad Zamorano, Honduras*.

[34] Jay, J.; Loessner, M.; Golden, D. 2005. "Modern Food Microbiology". *Springer Science & Business Media: Zurich, Suiza*.