International Food Research Journal 24(6): 2466-2473 (December 2017)
Journal homepage: *http://www.ifrj.upm.edu.my*

# Investigation on the influence of shred heights in pork muscle on quality characteristics of *balangu*

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**Article history**

*Received: 16 September 2016*
*Received in revised form: 22 October 2016*
*Accepted: 24October 2016*

**Keywords**

*Balangu*
*Shred heights*
*Volatile compounds*
*Consumer acceptability*
*Sensory attributes*
*Consumers' preference*

**Abstract**

This study reports on the influence of different shred heights in pork muscle on quality characteristics of a traditional grilled meat product balangu. Balangu was produced from pork muscle having different shred heights of 0.5, 0.75, 1.0, 1.25 and 1.5 mm; the traditional technique of preparation was adopted with little modification. The resulting products were assessed for volatile and sensory characteristics, using solid phase mass extraction gas chromatography-mass spectrometry (SPME-GSMS) and sensory panel respectively. Results showed presence of various volatile compounds belonging to different classes including ketones, acids, alcohols, esters, aromatic/cyclic hydrocarbons, alkanes/alkenes, nitrogeneous compounds, aldehydes and furans; some of the volatiles could not be classified under any of the classes. The area units, AU ($x10^3$) of the volatiles increased correspondingly with increase in shred heights of pork muscle. Among others, the major volatiles identified in balangu were acetone, 2-butanone, 3-methyl-1-butanol and 2,3-butanedione, having AUs of 4734, 1551, 1239 and 463 respectively in the sample made from shred height of 0.5 mm. Evaluation of sensory characteristics indicated that there was enhanced sensory preference for balangu prepared from shred heights of 0.5 and 0.75 in the attributes of aroma and appearance. On the other hand, balangu samples prepared from shred heights of 1.25 and 1.5 mm recorded better preference in the attributes of tenderness, taste and acceptability than those from lower shred heights. The finding concluded that optimal quantities of the major volatiles were obtained from balangu samples made from shred heights of 0.5, 0.75 and 1.0 mm, thus giving them advantage over others. Moreover, slight variation occurred in consumers' preference for the different balangu samples in the sensory attributes tested. This is a novel study, as no previous report is known on influence of shred heights on quality characteristics of balangu produced from pork muscle.



## Introduction

The contribution of desirable volatiles to the eating quality of meat is very important in order to determine how such volatiles can be achieved through production and processing (Elmore and Mottram, 2009). Meat volatiles are thermally derived; during cooking, a complex series of thermally induced reactions occur between non-volatile components of lean and fatty tissues, and this may result in a large number of reaction products (Olaoye, 2015). The volatile compounds formed in these reactions are largely responsible for the characteristic flavour of cooked meat. Furthermore, many enzymatic and non-enzymatic reactions can occur in cooked meat, giving rise to volatile compounds such as aldehydes, carboxylic acids, alcohols, ketones, esters, sulfur compounds, nitrogenous compounds, terpenes, alkanes and alkenes, aromatic and cyclic hydrocarbons. Some of the reactions implicated to be responsible for the generation of these volatiles include protein degradation, lipid degradation and oxidation, Maillard reactions, and Strecker degradation of amino acids (Huan *et al*., 2005). These volatile compounds have been reported to contribute to flavour development in meat and other food products (Du and Ahn, 2001; Ruiz *et al*., 2001; Olaoye, 2016).

Balangu is a type of suya, traditional Nigerian meat product, commonly prepared from raw meat, especially beef with the addition of various spices and cooked by grilling. It is usually eaten as delicacies and has associated sensory characteristics which play important role in acceptance by consumers (Olaoye, 2016). Balangu is a popular traditionally processed Nigerian meat product that is served or sold along streets or in club houses. It is a boneless meat product usually cooked bare on wire gauze on glowing charcoals, and is not hanged on sticks unlike tsire (Alonge and Hiko, 1981). The meat pieces are spiced

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with peanut cake, spices, vegetable oil, salt or other flavorings (Olaoye, 2016).

Some studies have been reported on different types of cooked meat products; for example, Omojola (2008) reported the yield and organoleptic characteristics of a Nigerian traditional grilled stick meat prepared from three different muscles of a matured bull. In another study, Olaoye and Dodd (2010) evaluated the effect of bacteriocinogenic *Pediococcus acidilactici* as protective culture on preservation of similar traditional stick mea product, and noted positive influence of the culture on shelf life and shelf stability during storage. Additionally, Olaoye (2015) reported a study on the effect of storage period on flavour profile and consumers' acceptability of tsire, a Nigerian stick grilled meat product prepared from beef. Although, many of these studies were carried out on possible extension in the shelf life and stability of cooked meat product, such reports have been limited to preparation from muscle of cow (i.e. beef). Also, the studies only considered uniform shreds of beef muscle, whereas variation in the shred heights may have pronounced effect on the quality attributes of the meat product.

Since no study has been known in the said area, research effort is required to evaluate possible effect of the use of different shred heights in muscle of meat on the product's quality. Hence, the current finding was carried out to investigate the influence of variations in the shred of pork muscle on quality characteristics of balangu produced from the different shreds. The quality characteristics evaluated were volatiles and sensory acceptability of the product.

## Materials and Methods

### *Source of raw materials*

The pork muscle used in this study was purchased from a butcher's shop in the city of Nottingham, Nottinghamshire, UK. The muscle samples were conveyed to the laboratory over ice crystals for immediate processing. The spices used included ground red pepper (*Capsicum* sp.), onions *(Alium cepa)*, ginger *(Zingiber officinalis)*, groundnut *(Arachis hypogaea)* and salt (Onilude *et al*., 2002) which were obtained from a Nigerian shop in the same city.

### *Preparation of balangu*

The traditional processing technique normally employed for preparation of balangu, howbeit with slight modification (Olaoye, 2016). Fresh pork muscle samples were washed in sterile distilled water (SDW), cut into different shred heights (mm) of various length, breadth and height (i.e. 10 x 6 x 0.5 mm, 10 x 6 x 0.75 mm, 10 x 6 x 1 mm, 10 x 6 x 1.25 mm and 10 x 6 x 1.5 mm). The emphasis in this study was variation in shred heights of 0.5, 0.75, 1.0, 1.25 and 1.5 mm; the various muscle shreds were thereafter kept and processed separately; curing of pork muscle shred was carried out by the addition of mixed spices on surfaces and spread on the surface using disinfected spatula. The muscle shreds were also turned severally in the spice mixtures to ensure thorough and uniform distribution on the entire surfaces. They were then grilled on wire gauze over glowing charcoals at 120-140$^{o}$C until well grilled (20-45 min), with intermittent turning to ensure even cooking. Cooking time of the meat cuts was longer for samples with higher shred heights compared to lower heights. Groundnut oil was sprinkled on the muscle shreds, before and during grilling, to simulate the traditional technique of avoiding burning or charring (Onilude *et al*., 2002). The spice mixtures used were produced by grinding ground red pepper (23%), groundnut (52%), ground ginger (20%) and salt (5%) into powdery form.

### *Analysis of volatiles in balangu samples*

The volatiles in the different balangu samples that resulted from the muscle shreds were analyzed using solid phase micro extraction Gas Chromatography-mass spectrometry (SPME GC-MS). This was performed by placing 2 g of sample in 20 ml headspace vial (22.5 mm x 75.5 mm, Grace Alltech, UK). The vial was sealed with a magnetic cap (20mm diameter, 5mm centre, PTFE/Silicone Liner; Grace Alltech) using a Crimper (Part no 60045, Alltech Associates Inc., USA) and allowed to equilibrate at room temperature (22$^{o}$C) for approximately 30 min before commencement of analysis. A Stableflex fibre, coated with 50/30 µm divinylbenzenecarboxen on polydimethylsiloxane bonded to a flexible fused silica core (Supelco, Bellefonte, PA, 16823-0048 USA) was used for the extraction of the volatiles. For volatile sampling, an extraction time of 15 min at room temperature was used while desorption time was set to 4 min at 230$^{o}$C.

GC–MS was carried out using a Trace GC Ultra gas chromatograph (Thermo Electron Corporation) and a DSQ mass spectrometer (1.4.1 SP3 Thermo Electron Corporation, USA). The GC–MS settings used were as follows: samples were injected in splitless mode with a PAL auto-sampler. Chromatography was carried out with a TRACE GC 2000 series gas chromatograph using a ZB-WAX capillary column (Serial no 162147, Order no 7HG-G007-22, L 30m x I.D. 0.25mm x df 1µm, USA).

Table 1. Occurrence of alcohols and esters in the balangu samples produced from different shreds of pork muscle

| | | Pork muscle shred heights (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | | 0.75 | | 1.0 | | 1.25 | | 1.5 | | |
| Volatiles | RT | Value | Sd | Value | Sd | Value | Sd | Value | Sd | Value | Sd | *P*-value |
| ethanol | 4.52 | $122^{a}$ | 19 | $113^{a}$ | 27 | $101^{b}$ | 24 | $88^{b}$ | 15 | $90^{b}$ | 8 | 0.0217 |
| 1-Propanol | 6.34 | $19^{a}$ | 4 | $18^{a}$ | 5 | $17^{a}$ | 2 | $14^{b}$ | 5 | $9^{b}$ | 3 | 0.0423 |
| 3-Ethyl-4-nonanol | 18.09 | $19^{a}$ | 3 | $15^{a}$ | 6 | $14^{a}$ | 7 | $12^{a}$ | 2 | $9^{b}$ | 1 | 0.0351 |
| 3-methyl-2-Butanol | 7.90 | $39^{a}$ | 11 | $38^{a}$ | 16 | $33^{a,b}$ | 9 | $30^{b}$ | 7 | $31^{b}$ | 5 | 0.0524 |
| Tricyclo[5.2.1.0(1,5)]dec-5-en-8-ol | 8.55 | $27^{a}$ | 13 | $25^{a}$ | 9 | $19^{a,b}$ | 7 | $15^{b}$ | 8 | $15^{b}$ | 5 | 0.0162 |
| 3-methyl-1-Butanol | 9.66 | $1239^{a}$ | 123 | $921^{a}$ | 75 | $830^{b}$ | 82 | $760^{b}$ | 47 | $653^{c}$ | 13 | 0.0021 |
| 1-Pentanol | 10.51 | $45^{a}$ | 13 | $38^{a}$ | 12 | $34^{a}$ | 9 | $35^{a}$ | 7 | $24^{c}$ | 6 | 0.0012 |
| 3-methyl-3-Buten-1-ol | 10.61 | $27^{a}$ | 14 | $26^{a}$ | 12 | $23^{a}$ | 9 | $19^{b}$ | 10 | $17^{b}$ | 6 | 0.0015 |
| 4-Methyl-2-hexanol | 11.78 | $67^{a}$ | 22 | $62^{a}$ | 18 | $53^{a}$ | 12 | $40^{b}$ | 13 | $35^{b}$ | 7 | 0.0251 |
| 1-Hexanol | 12.49 | $38^{a}$ | 12 | $35^{a}$ | 10 | $31^{a,b}$ | 14 | $27^{b}$ | 8 | $23^{b}$ | 9 | 0.0035 |
| 3-Pentanol | 12.75 | $49^{a}$ | 9 | $43^{a}$ | 11 | $35^{b}$ | 7 | $33^{b}$ | 3 | $27^{b}$ | 9 | 0.0027 |
| p-menth-1-en-8-ol | 18.75 | $16^{a}$ | 1 | $12^{a}$ | 4 | $13^{a}$ | 4 | $11^{a,b}$ | 5 | $9^{b}$ | 4 | 0.0244 |
| Phenylethyl_Alcohol | 22.20 | $25^{a}$ | 15 | $21^{a}$ | 11 | $19^{a}$ | 9 | $20^{a}$ | 4 | $14^{a}$ | 6 | 0.0258 |
| 3-phenoxy-1-Propanol | 23.90 | $12^{a}$ | 1 | $11^{a}$ | 3 | $9^{a}$ | 3 | $5^{b}$ | 1 | $6^{b}$ | 3 | 0.0167 |
| 1-Octen-3-ol | 14.25 | $55^{a}$ | 15 | $51^{a}$ | 18 | $45^{a,b}$ | 12 | $39^{b}$ | 9 | $33^{b}$ | 7 | 0.0263 |
| 2,6-dimethyl-4-Heptanol | 15.10 | $121^{a}$ | 25 | $116^{a}$ | 27 | $102^{a}$ | 18 | $96^{b}$ | 10 | $87^{b}$ | 11 | 0.0513 |
| 3-methoxy-2-Butanol | 15.57 | $267^{a}$ | 89 | $248^{a}$ | 65 | $236^{a}$ | 55 | $202^{a}$ | 34 | $178^{b}$ | 20 | 0.0127 |
| Acetic_acid,_pentyl_ester | 7.99 | $192^{a}$ | 30 | $188^{a}$ | 17 | $162^{a}$ | 13 | $143^{a}$ | 20 | $99^{b}$ | 6 | 0.0126 |
| Methyl_uronate | 13.29 | $15^{a}$ | 5 | $12^{a}$ | 7 | $13^{a}$ | 5 | $9^{b}$ | 3 | $5^{b}$ | 2 | 0.0218 |
| Acetic_acid,_hexyl_ester | 10.97 | $97^{a}$ | 27 | $89^{a}$ | 21 | $76^{a}$ | 15 | $54^{b}$ | 13 | $39^{b}$ | 5 | 0.0185 |
| Methyl_6-(2-furoyl) hexanoate | 15.74 | $59^{a}$ | 23 | $52^{a}$ | 18 | $49^{a}$ | 16 | $30^{b}$ | 9 | $19^{b}$ | 7 | 0.0219 |

Values are means of Area units, AU ($x10^3$) measured in three replicated samples; RT, retention time (min); Sd, standard deviation; Values with different superscripts across rows are significantly different ($P < 0.05$)

Helium was employed as the carrier gas, at a constant pressure of 15 psi and splitless time of 1 min. The oven temperature programme was as follows: an initial temperature of 40°C was maintained for 1 min, with ramps 8°C/min to 200°C and 10°C/min to a final temperature of 230°C. Mass spectrometry (MS) was performed with a DSQ mass spectrometer. The mass spectrometer was operated in positive ionisation electron impact mode (EI+) at electron energy of 70 eV. The scan time was 0.29 s. The detector was operated in scan mode, scanning from m/z 20 to 210. Source temperature was 200°C. The data generated were processed with Xcalibur TM 1.4 SR1 (Thermo Electron Corporation) software.

The flavour compounds in the tsire samples were identified by comparing their mass spectra and retention times with those in the National Institute of Standards and Technology (NIST) mass spectral library and matching them with standard compounds and data reported in the literature (Liu *et al.*, 2013; Fadel *et al.*, 2015). The chemical compounds (Sigma-Aldrich, Gillingham, UK) used as standards were of GC grade (≥99% purity). Results were reported as relative abundance expressed as total area counts ($AU \times 10^3$).

*Sensory evaluation*

The balangu samples that depended on the different pork muscle shreds were subjected to sensory evaluation. Samples were evaluated for the attributes of aroma, appearance, tenderness, taste and acceptability with the help of a 20 member panel, which composed of panelists were already familiar with the product. Samples were presented to the panellists in three coded replicates and were asked to allocate scores to them using a 9-point hedonic scale, from 1-dislike extremely to 9-like extremely. The data obtained were subjected to statistical analysis to determine significant differences among samples.

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*Statistical analysis*

The influence of different pork muscle shreds of various heights on balangu were determined by analysis of variance (ANOVA) using the statistic software, Design expert (Stat-Ease Inc., East Hennepin Ave, Minneapolis, Version 6.0.6). Significant difference was determined at $P < 0.05$.

## Results and Discussion

The occurrence of volatile compounds of alcohols and esters in the different samples of the balangu prepared from the various pork muscle of varying shred heights 0.5, 0.75, 1.0, 1.25 and 1.5 mm are presented in Table 1. One of the volatile compound of alcohol, 3-methyl-1-butanol, occurred more abundantly than others ($P < 0.05$) having the highest area unit, AU ($x10^3$). The highest AU of 1239 was recorded for the volatile compound in the 0.5 mm balangu sample while the lowest AU (653) was obtained for 1.5 mm sample. It is interesting to note that significant difference ($P = 0.0021$) occurred in the AU of this compound among balangu samples, indicating that muscle shred heights had significant effect on the compound. Research investigation carried out by Cassaburi *et al.* (2011) and Olaoye

Table 2. Occurrence of aromatic/cyclic hydrocarbons and alkanes/alkenes in the balangu samples produced from different shreds of pork muscle

| | | Pork muscle shred heights (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | | 0.75 | | 1.0 | | 1.25 | | 1.5 | | |
| Volatiles | RT | Value | Sd | Value | Sd | Value | Sd | Value | Sd | Value | Sd | *P*-value |
| Ethylbenzene | 8.25 | $22^{a}$ | 2 | $18^{a}$ | 4 | $16^{a}$ | 8 | $12^{ab}$ | 3 | $10^{b}$ | 3 | 0.0123 |
| o-Xylene | 8.41 | $27^{a}$ | 3 | $20^{a}$ | 5 | $18^{a}$ | 7 | $12^{ab}$ | 2 | $10^{b}$ | 4 | 0.0237 |
| (2-methoxy-2-propenyl)-Benzene | 14.37 | $71^{a}$ | 9 | $59^{a}$ | 12 | $53^{a,b}$ | 14 | $54^{ab}$ | 9 | $45^{b}$ | 6 | 0.0363 |
| Phenyl-pentamethyl-disiloxane | 14.86 | $31^{a}$ | 10 | $21^{a}$ | 8 | $16^{b}$ | 5 | $15^{b}$ | 2 | $12^{b}$ | 4 | 0.0253 |
| Himachala-2,4-diene | 19.06 | $73^{a}$ | 17 | $64^{a}$ | 8 | $61^{a}$ | 12 | $53^{b}$ | 10 | $49^{b}$ | 7 | 0.0348 |
| Heptane | 1.83 | $89^{a}$ | 23 | $84^{a}$ | 18 | $79^{a}$ | 21 | $67^{b}$ | 9 | $60^{b}$ | 13 | 0.0482 |
| 11s-Himachala-3(12),4-diene | 19.17 | $41^{a}$ | 7 | $32^{a}$ | 6 | $29^{a}$ | 9 | $27^{a,b}$ | 7 | 23b | 5 | 0.0236 |
| hexamethyl-Cyclotrisiloxane | 19.54 | $22^{a}$ | 2 | $15^{a}$ | 4 | $16^{a}$ | 5 | $11^{b}$ | 2 | $9^{b}$ | 1 | 0.0172 |
| Octane | 2.52 | $39^{a}$ | 19 | $38^{a}$ | 15 | $30^{ab}$ | 8 | $29^{b}$ | 12 | $25^{b}$ | 4 | 0.0218 |
| Cyclodecane | 6.19 | $27^{a}$ | 2 | $21^{a}$ | 5 | $17^{a}$ | 3 | $13^{b}$ | 5 | $9^{b}$ | 2 | 0.0327 |
| Pentane | 1.31 | $131^{a}$ | 16 | $123^{a}$ | 12 | $110^{ab}$ | 17 | $106^{ab}$ | 9 | $101^{b}$ | 19 | 0.0325 |
| (E)-3-Dodecene | 10.11 | $27^{a}$ | 2 | $17^{a}$ | 5 | $16^{a}$ | 3 | $13^{b}$ | 4 | $9^{b}$ | 2 | 0.0429 |
| 1,2-15,16-Diepoxyhexadecane | 17.23 | $70^{a}$ | 13 | $52^{a}$ | 9 | $45^{ab}$ | 10 | $43^{b}$ | 12 | $39^{b}$ | 3 | 0.0189 |
| Hexane | 1.48 | $21^{a}$ | 7 | $17^{a}$ | 6 | $15^{ab}$ | 3 | $16^{ab}$ | 6 | $11^{b}$ | 4 | 0.0293 |
| Cyclopentene | 1.65 | $91^{a}$ | 18 | $81^{a}$ | 23 | $74^{a}$ | 15 | $64^{ab}$ | 9 | $57^{b}$ | 11 | 0.0235 |
| 2-propenylidene-Cyclobutene | 6.53 | $82^{a}$ | 15 | $62^{a}$ | 9 | $55^{ab}$ | 14 | $49^{b}$ | 8 | $43^{b}$ | 13 | 0.0172 |
| 1-pentyl-2-propyl-Cyclopropane | 8.08 | $16^{a}$ | 3 | $12^{a}$ | 4 | $10^{ab}$ | 5 | $8^{b}$ | 2 | $7^{b}$ | 1 | 0.0325 |

Values are means of Area units, AU ($x10^3$) measured in three replicated samples; RT, retention time (min); Sd, standard deviation; Values with different superscripts across rows are significantly different ($P < 0.05$)

(2015) reported the identification of 3-methyl-1-butanol in cooked meat products; the authors noted that the compound occurred in abundant amounts than other alcohols. Another compound, 3-methoxy-2-butanol, was next to 3-methyl-1-butanol in concentration, having AU value of 267 in the 0.5 mm sample. All other alcohols had AU of below 200 in all samples of balangu from the various shred heights of pork muscle. The alcohols generally decreased in area units with corresponding increase in the muscle shred heights. The esters had AU of below 200, with acetic acid-pentyl ester having the highest value of 192 in the 0.5 mm sample, followed by acetic acid-hexyl ester having AU of 97 in the same sample. Values assumed similar pattern recorded for alcohols, decreasing with corresponding decrease in the muscle shred heights. Statistical analysis of the alcohols and esters indicate that significant difference ($P < 0.05$) occurred between the balangu samples in most of the volatile compounds that were identified. The occurrence of alcohols and esters in the balangu samples are in agreement with the study of Gianelli *et al.* (2012) who reported similar volatile compounds in Chilean traditional meat products, charqui and longaniza sausage.

Shown in Table 2 are the AUs of the volatile compounds of aromatic/cyclic hydrocarbons and alkanes/alkenes that were identified in the balangu samples. All volatile compounds had AUs of below 150; pentane had the highest value of 131 recorded in the 0.5 mm sample while the lowest value (101) was recorded in the 1.5 mm sample. Heptane was next in to pentane, having AU of 89 in the 0.5 mm tsire sample. Varying degree of significant difference ($P < 0.05$) was observed between the lower (0.5/0.75 mm) and higher (1.25/1.5 mm) muscle shred heights of balangu samples, and this may indicate possible influence of shred heights on the volatile compounds of the meat product. Some of the compounds of aromatic/cyclic hydrocarbons and alkanes/alkenes recorded in the balangu samples in this study have been reported by Olaoye (2015b) in a grilled meat product tsire, though the author did not investigate the effect of shred heights in muscle on the associated volatiles.

The AUs of volatile compounds belonging to ketones (18) and acids (8) identified in the balangu samples are shown in Table 3. Results indicated that the volatile compounds occurred in different concentrations, which were obviously dependent on the muscle shred heights. Among the ketone compounds, the AUs of acetone in the various balangu samples were higher than other compounds; the highest value of 4734 was recorded for the 0.5 mm sample while the lowest (1304) was obtained for the 1.5 mm counterpart. The compound 2-butanone was next in concentration to acetone, having an AU of 1551 for the 0.5 mm sample. Generally, AUs of the ketone compounds in the various samples decreased with corresponding increase in the shred heights of pork muscle. Significant difference ($P < 0.05$) was recorded in the AUs of most of the ketone compounds in the various samples, indicating that muscle shred heights had significant effect on the associated volatile compounds.

Compounds belonging to the group of ketones have been reported as products of lipid auto-oxidation and microbial metabolism which may have great

Table 3. Occurrence of ketones and acids in the balangu samples produced from different shreds of pork muscle

| | | Pork muscle shred heights (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | | 0.75 | | 1.0 | | 1.25 | | 1.5 | | |
| Volatiles | RT | Value | Sd | Value | Sd | Value | Sd | Value | Sd | Value | Sd | *P*-value |
| 3-Methyl-2-Butanone (Diacetyl) | 4.48 | $77^{a}$ | 12 | $64^{a}$ | 21 | $60^{a}$ | 19 | $45^{b}$ | 9 | $36^{b}$ | 3 | 0.0032 |
| 2,3-Butanedione | 5.32 | $463^{a}$ | 67 | $321^{a}$ | 111 | $209^{b}$ | 43 | $145^{b}$ | 13 | $98^{c}$ | 25 | 0.0012 |
| 6-Methyl-5-Hepten-2-one | 12.39 | $91^{a}$ | 16 | $63^{a}$ | 23 | $45^{b}$ | 12 | $33^{b}$ | 9 | $12^{c}$ | 5 | 0.0024 |
| 2-Hydroxy-3-pentanone | 13.01 | $49^{a}$ | 12 | $43^{a}$ | 5 | $29^{b}$ | 7 | $13^{c}$ | 6 | $9^{c}$ | 3 | 0.0343 |
| 6-Heptyltetrahydro-2H-Pyran-2-one | 17.88 | $22^{a}$ | 5 | $15^{a}$ | 4 | $11^{ab}$ | 6 | $6^{b,c}$ | 3 | $3^{c}$ | 1 | 0.0432 |
| Methyl_Isobutyl_Ketone | 5.82 | $81^{a}$ | 21 | $45^{b}$ | 19 | $27^{c}$ | 9 | $21^{c}$ | 5 | $10^{d}$ | 3 | 0.0386 |
| 3-Methyl-2-pentanone | 6.01 | $101^{a}$ | 26 | $76^{ab}$ | 22 | $63^{b}$ | 18 | $45^{c}$ | 17 | $34^{c}$ | 12 | 0.0596 |
| 2-Hexanone | 7.26 | $41^{a}$ | 13 | $31^{a}$ | 11 | $20^{b}$ | 2 | $14^{b,c}$ | 5 | $9^{c}$ | 2 | 0.0281 |
| 5-Methyl-2-Hexanone | 8.45 | $155^{a}$ | 56 | $160^{a}$ | 32 | $123^{a}$ | 33 | $98^{b}$ | 13 | $78^{b}$ | 21 | 0.0621 |
| Acetone | 2.90 | $4734^{a}$ | 103 | $3301^{b}$ | 59 | $2596^{bc}$ | 47 | $2098^{c}$ | 74 | $1304^{d}$ | 45 | 0.0425 |
| 2-Butanone | 4.01 | $1551^{a}$ | 120 | $1395^{a}$ | 73 | $1123^{b}$ | 76 | $983^{b}$ | 71 | $680^{c}$ | 84 | 0.0638 |
| 2-Heptanone | 9.29 | $150^{a}$ | 75 | $125^{a}$ | 43 | $98^{b}$ | 32 | $67^{b}$ | 16 | $43^{c}$ | 8 | 0.0124 |
| 6-Methyl-2-Heptanone | 10.38 | $47^{a}$ | 21 | $34^{a}$ | 9 | $23^{a}$ | 11 | $12^{b}$ | 5 | $4^{c}$ | 2 | 0.0253 |
| 3-Hydroxy-3-methyl-2-butanone | 10.68 | $775^{a}$ | 121 | $657^{a}$ | 102 | $523^{b}$ | 125 | $324^{c}$ | 98 | $125^{d}$ | 76 | 0.0197 |
| 5-Methyl-2-Heptanone | 10.75 | $91^{a}$ | 43 | $72^{a}$ | 32 | $54^{b}$ | 21 | $32^{c}$ | 17 | $17^{d}$ | 6 | 0.0173 |
| 2-Octanone | 11.32 | $52^{a}$ | 21 | $38^{ab}$ | 15 | $29^{b}$ | 17 | $19^{c}$ | 6 | $8^{d}$ | 2 | 0.0371 |
| 3-Hydroxy-2-Butanone (Acetoin) | 11.65 | $581^{a}$ | 89 | $430^{ab}$ | 102 | $385^{b}$ | 89 | $220^{c}$ | 74 | $98^{d}$ | 32 | 0.0470 |
| 1-Hydroxy-2-Propanone | 12.00 | $113^{a}$ | 65 | $98^{a}$ | 26 | $75^{b}$ | 22 | $56^{c}$ | 19 | $34^{d}$ | 13 | 0.0349 |
| 3-methyl-Butanoic acid | 18.45 | $163^{a}$ | 34 | $165^{a}$ | 26 | $143^{a}$ | 18 | $123^{b}$ | 26 | $109^{b}$ | 19 | 0.0465 |
| Hexanoic acid | 21.14 | $19^{a}$ | 4 | $21^{a}$ | 6 | $18^{a}$ | 5 | $15^{ab}$ | 3 | $12^{b}$ | 4 | 0.0127 |
| 2-methyl-Propanoic acid | 16.77 | $17^{a}$ | 4 | $9^{a}$ | 5 | $5^{b}$ | 2 | $5^{b}$ | 3 | $3^{b}$ | 1 | 0.0425 |
| Butanoic_acid | 17.80 | $19^{a}$ | 12 | $16^{a}$ | 8 | $14^{a}$ | 6 | $10^{b}$ | 5 | $9^{b}$ | 3 | 0.0216 |
| Acetic acid | 14.92 | $81^{a}$ | 17 | $65^{a}$ | 12 | $55^{a}$ | 9 | $36^{b}$ | 8 | $18^{c}$ | 4 | 0.0126 |
| Propanoic acid | 16.34 | $52^{a}$ | 19 | $37^{a}$ | 9 | $31^{b}$ | 12 | $23^{b}$ | 4 | $15^{c}$ | 5 | 0.0261 |
| Methylenecyclopropanecarboxylic acid | 18.15 | $29^{a}$ | 7 | $28^{a}$ | 8 | $23^{ab}$ | 4 | $19^{b}$ | 5 | $15^{b}$ | 7 | 0.0162 |
| 2-methyl-Hexanoic acid | 18.43 | $126^{a}$ | 26 | $116^{a}$ | 27 | $105^{ab}$ | 31 | $97^{b}$ | 17 | $75^{c}$ | 13 | 0.0325 |

Values are means of Area units, AU ($x10^3$) measured in three replicated samples; RT, retention time (min); Sd, standard deviation; Values with different superscripts across rows are significantly different ($P < 0.05$)

influence on volatile compounds of meat and meat products (Martin *et al*., 2009). One of the important ketone compounds detected in the present finding was 2,3-butanedione (diacetyl) which origination has been attributed to citrate metabolism by microbial activities especially lactic acid bacteria, LAB (Partidário *et al.* 2006; Olaoye, 2015). The compound is of significance as a result of its antimicrobial activity against some spoilage and pathogenic organisms of food products, especially meat (Olaoye and Onilude, 2011). Apart from its antimicrobial activity, the compound has been reported to impart positively on sensory quality of meat products (Olaoye, 2016). The low levels of diacetyl recorded in the balangu samples may be attributed to minimal metabolic activities of microorganisms, since the product only stayed for short period (less than four hours) after production before analysis. Olaoye (2016) also reported low concentrations of the compound in a grilled meat product made from beef muscle shred height of 0.5 mm. This was similar to those obtained in the present study, especially for the samples from pork muscle shred heights of 0.5 and 1 mm. Some compounds of ketones identified in this study, among which were 2-butanone, 2-heptanone and 2-hexanone, could play significant role in the sensory characteristics of the product; this is as a result of their ability to contribute to flavour development in meat products, especially when present in optimal concentrations (Estevez *et al*., 2005). Another important compound identified in the balangu product was 3-hydroxy-2-butanone (acetoin), commonly produced by metabolic activities of heterolactic lactic acid bacteria. The compound has been identified to be of significance as it may contribute desirably to flavour quality of food (Wierda *et al*., 2006).

Among the acids that were identified, 2-methyl-butanoic acid had higher AU than others in the different balangu samples. The highest AU (163) was recorded for the compound in the sample produced from muscle shred height of 0.5 mm while the lowest (109) was obtained for the 1.5 mm sample. The AU of 2-methyl-butanoic acid decreased progressively with increase in the pork muscle shred heights. Next to 2-methyl-butanoic acid was 2-methyl-hexanoic acid in term of AUs, which recorded similar trend to that of the former; the highest AU of 126 was recorded for the 0.5 mm sample while the lowest value (75) was obtained for the 1.5 mm sample. Of all the acids identified in the balangu product, 2-methyl-propionic acid had lowest values of AUs in comparison with others. Generally, AUs of the acids decreased in the pork meat product with corresponding decrease in pork muscle shred heights. The occurrence of compounds of ketones and acids in a grilled meat product tsire has been reported by other research investigators (Olaoye, 2015; Olaoye, 2016).

It was observed in the present study that the patterns of the volatile compounds of ketones and acids recorded in the balangu samples may have been influenced by the nature and quantity of the spices added prior to production. The samples with lower muscle shred heights could probably have deeper penetration of spices than those with bigger heights, and this may have effect on the product during grilling. No previous report is however available on

Table 4. Occurrence of nitrogenous compounds, aldehydes and furans in the balangu samples produced from different shreds of pork muscle

| | | Pork muscle shred heights (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | | 0.75 | | 1.0 | | 1.25 | | 1.5 | | |
| Volatiles | RT | Value | Sd | Value | Sd | Value | Sd | Value | Sd | Value | Sd | *P*-value |
| 2,3-dimethyl-Pyrazine | 12.71 | $35^{a}$ | 13 | $31^{a}$ | 8 | $27^{a}$ | 7 | $20^{ab}$ | 5 | $22^{b}$ | 7 | 0.0263 |
| trimethyl-Pyrazine | 13.73 | $801^{a}$ | 102 | $710^{a}$ | 89 | $620^{ab}$ | 26 | $530^{b}$ | 34 | $397^{c}$ | 49 | 0.0327 |
| 3-ethyl-2,5-dimethyl-Pyrazine | 14.44 | $61^{a}$ | 3 | $51^{a}$ | 10 | $43^{ab}$ | 14 | $37^{b}$ | 8 | $29^{b}$ | 6 | 0.0438 |
| 1-methyl-1H-Pyrrole | 8.58 | $161^{a}$ | 13 | $142^{a}$ | 27 | $135^{ab}$ | 19 | $127^{b}$ | 21 | $115^{c}$ | 9 | 0.0182 |
| 3-methyl-Butanenitrile | 8.28 | $22^{a}$ | 2 | $12^{a}$ | 6 | $13^{a}$ | 3 | $10^{ab}$ | 4 | $11^{b}$ | 2 | 0.0430 |
| Tetraacetyl-d-xylonic_nitrile | 23.91 | $20^{a}$ | 7 | $20^{a}$ | 8 | $15^{a}$ | 2 | $11^{a}$ | 3 | $6^{b}$ | 2 | 0.0034 |
| 2-methyl-_Pyrazine | 11.15 | $91^{a}$ | 18 | $73^{a}$ | 20 | $65^{ab}$ | 16 | $53^{bc}$ | 9 | $51^{c}$ | 14 | 0.0434 |
| 2,5-dimethyl-Pyrazine | 12.22 | $41^{a}$ | 45 | $371^{a}$ | 32 | $344^{a}$ | 25 | $323^{a}$ | 43 | $307^{b}$ | 64 | 0.0329 |
| tetramethyl-Pyrazine | 14.95 | $141^{a}$ | 12 | $126^{a}$ | 21 | $112^{a}$ | 19 | $87^{b}$ | 17 | $59^{b}$ | 9 | 0.0483 |
| Nonanal | 13.42 | $41^{a}$ | 12 | $21^{a}$ | 7 | $15^{a,b}$ | 5 | $11^{b}$ | 1 | $9^{b}$ | 3 | 0.0213 |
| 2-methyl-Butanal | 4.19 | $69^{a}$ | 14 | $62^{a}$ | 17 | $45^{b}$ | 9 | $37^{b}$ | 5 | $31^{c}$ | 8 | 0.0435 |
| Benzaldehyde | 16.22 | $29^{a}$ | 9 | $26^{a}$ | 10 | $21^{ab}$ | 7 | $15^{b}$ | 9 | $8^{c}$ | 1 | 0.0238 |
| 3-methyl-Butanal | 4.26 | $65^{a}$ | 21 | $54^{a}$ | 17 | $46^{a}$ | 19 | $37^{b}$ | 8 | $23^{b}$ | 14 | 0.0327 |
| Heptanal | 9.36 | $41^{a}$ | 9 | $33^{a}$ | 12 | $25^{a}$ | 7 | $17^{b}$ | 5 | $11^{b}$ | 1 | 0.0364 |
| 2-pentyl-Furan | 10.21 | $21^{a}$ | 2 | $17^{a}$ | 5 | $13^{ab}$ | 2 | $8^{b}$ | 3 | $3^{b}$ | 2 | 0.0483 |
| 2,5-dimethyl-Furan | 14.99 | $11^{a}$ | 1 | $11^{a}$ | 3 | $8^{ab}$ | 2 | $6^{ab}$ | 2 | $7^{b}$ | 2 | 0.0348 |
| 3,4-dihydro-4,4,7-trimethyl-Coumarin13.95 | $31^{a}$ | 9 | $20^{a}$ | 5 | $16^{a}$ | 9 | $9^{b}$ | 3 | $9^{b}$ | 2 | 0.0430 | |
| 5-Azacytosine | 17.46 | $57^{a}$ | 10 | $47^{a}$ | 18 | $40^{ab}$ | 12 | $31^{b}$ | 14 | $31^{b}$ | 3 | 0.0216 |
| (+)-Epi-bicyclosesquiphellandrene | 19.37 | $39^{a}$ | 9 | $36^{a}$ | 10 | $27^{b}$ | 8 | $20^{b}$ | 10 | $10^{c}$ | 2 | 0.0213 |
| Eucalyptol | 9.83 | $40^{a}$ | 10 | $29^{a}$ | 5 | $20^{ab}$ | 4 | $15^{b}$ | 7 | $10^{b}$ | 3 | 0.0347 |
| methoxy-phenyl-Oxime | 19.04 | $62^{a}$ | 16 | $50^{a}$ | 13 | $39^{ab}$ | 7 | $30^{b}$ | 16 | $23^{c}$ | 9 | 0.0436 |
| Borneol | 18.96 | $71^{a}$ | 21 | $55^{a}$ | 17 | $47^{a}$ | 18 | $38^{b}$ | 7 | $23^{b}$ | 9 | 0.0328 |

Values are means of Area units, AU (x$10^{3}$) measured in three replicated samples; RT, retention time (min); Sd, standard deviation; Values with different superscripts across rows are significantly different (P < 0.05)

the effect of pork muscle shred heights on volatile profiles of balangu that may be used for possible comparison with results obtained in the present study.

Results in the present study further showed that nine nitrogeneous compounds were identified in the balangu samples, among which trimethyl-pyrazine occurred in significant quantities (P < 0.05) in the 0.5 and 1.0 mm samples than others (Table 4). The highest AU of 801 was recorded for the 0.5 mm sample, followed by 710 in the 0.75 mm sample while lower values were recorded for others. Results further revealed that pork muscle shred height had significant effect on the occurrence of trimethyl-pyrazine in the balangu. The aldehydes identified in balangu in the present finding were 2-methyl-butanal, 3-methyl-butanal, heptanal, benzaldehyde and nonanal (Table 4); among these, 2-methyl-butanal had the highest AU of 69 in the 0.5 mm sample, while lower values were recorded in others. The AUs decreased with corresponding increase in the muscle shred heights and significant difference (P < 0.05) was recorded among the samples. The compounds 2-pentyl-furan and 2,5-dimethyl-furan were the only furans were identified in the balangu samples, with the former having higher AUs than the other.

The volatile compounds which occurred in major quantities than others in the balangu samples and their AUs are shown in Figure 1. Overall, acetone had the highest AU of 4734, the value obtained in the sample produced from pork muscle shred height of 0.5 mm. The same compound recorded higher AUs in each of the balangu samples compared to other compounds. Among the major volatile compounds, 2-butanone, 2,3-butanedione, 3-methyl-1-butanol, trimethyl-pyrazine, and 3-hydroxy-2-butanone (acetoin) could be of significance in the balangu product (Olaoye, 2015; Olaoye, 2016). The quantities of most of these compounds varied significantly (P < 0.05) in the balangu samples; this was noted to be influenced by the muscle shred heights. Diacetyl (2,3-butanedione) has been noted to be advantageous due to its antimicrobial properties, while 2-butanone and 3-methyl-1-butanol have also been reported to have potential of contributing to flavour development in meat products, especially when present in optimal concentrations (Rivas-Canedo *et al.*, 2009; Olaoye, 2015). Hence balangu samples with optimal concentrations of the compounds in this study, especially samples from muscle shred heights of 0.5, 0.75, 1.0 and 1.25 mm may be favourably advantageous.

The hedonic mean scores of the sensory attributes of the balangu samples indicated that there was reduction in the preference of attributes of aroma and appearance in the samples prepared from muscle shred heights of 1.0, 1.25 and 1.5 mm when compared to their 0.5 and 0.75 mm counterparts. There were higher hedonic mean scores in the attributes of tenderness and taste of the 1.25 and 1.5 mm samples in comparison with others. The balangu samples

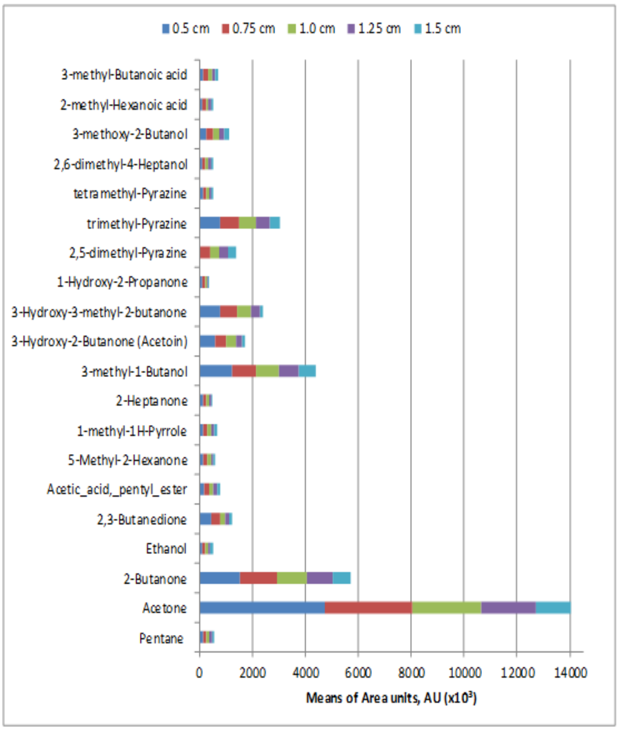

Figure 1. The major volatiles identified in the balangu samples produced from different shreds (0.5, 0.75, 1.0, 1.25 and 1.5 cm) of pork muscle

from 1.25 and 1.5 mm recorded better preference in the attribute of acceptability than others; mean scores of 8.7 and 8.6 were obtained for the respective samples. There was generally variation in the level of significant difference ($P < 0.05$) among the sensory attributes evaluated in the balangu samples.

From the results of this investigation, it was concluded that variation in shred heights of pork muscle had significant influence ($P < 0.05$) on the volatile compounds of balangu. Heights of 0.5, 0.75, and 1.0 mm of muscle shreds may be suitable for preparation of the meat product as a result of optimal concentrations of volatile compounds that may be of significance, including 2-butanone, 3-methyl-1-butanol, 2,3-butanedione, acetone and 3-hydroxy-2-butanone recorded in the product. This study recommended that muscle shred heights of higher than 1 mm may not be suitable for preparation of balangu from pork and probably other animal muscles.

## Ackowledgement

Authors appreciate the support received from the Division of Food Sciences, Sutton Bonington campus, Leics, University of Nottingham, UK.

## References

Alonge, D.O. and Hiko, A.A. 1981. Traditional methods of meat preservation and preparation in Nigeria. West African Farm Food Processing 1: 19-21.

Casaburi, A., Nasi, A., Ferrocino, I., Di Monaco, R., Mauriello, G., Villani, F. and Ercolini, D. 2011. Spoilage-related activity of *Carnobacterium maltaromaticum* strains in air-stored and vacuum-packed meat. Applied Environmental Microbiology 7: 7382-7393.

Du, M. and Ahn, D.U. 2001. Volatile substances of Chinese traditional Jinhua ham and Cantonese sausage. Journal of Food Science 66: 827-831.

Elmore, J.S. and Mottram, D.S. 2009. Flavour development in meat. In Kerry, J.P. and Ledward, D. (Eds.). Improving the sensory and nutritional quality of fresh meat 1st ed., p. 112-146. Cambridge: Woodhead Publishing.

Estevez, M., Ventanas, S. and Cava, R. 2005. Protein oxidation in frankfurters with increasing levels of added rosemary essential oil: effect on colour and texture deterioration. Journal of Food Science 70: 427–432.

Fadel, H.H.M., Samad, A.A., Kobeasy, M.I., Mageed, M.A. and Lotfy, S.N. 2015. Flavour quality and stability of an encapsulated meat-like process flavouring prepared from soybean based acid hydrolyzed protein. International Journal of Food Processing and Technology 2: 17-25.

Gianelli, M.P., Salazar, V., Mojica, L. and Friz, M. 2012. Volatile compounds present in traditional meat products (charqui and longaniza sausage) in Chile. Brazilian Archives in Biology and Technology 55: 603-612.

Huan, Y.J., Zhou, G.H., Zhao, G.M., Xu, X.L. and Peng, Z.Q. 2005. Changes in flavour compounds of dry-cured Jinhua ham during processing. Meat Science 71: 291-299.

Liu, C., Zhang, J., Zhou, Z., Hua, Z., Wan, H., Xie, Y., Wang, Z. and Deng, L. 2013. Analysis of volatile compounds and identification of characteristic aroma components of *Toona sinensis* (A. Juss.) Roem. using GC-MS and GC-O. Food and Nutrition Sciences 4: 305-314.

Martin, D., Antequera, T., Muriel, E., Perez-Palacios, T. and Ruiz, J. 2009. Volatile compounds of fresh and dry-cured loin as affected by dietary conjugated linoleic acid and monounsaturated fatty acids. Meat Science 81: 549–556.

Olaoye, O.A. 2015. A preliminary study on the effect of storage period on flavour profile and consumers' acceptability of tsire, a Nigerian stick meat. AASCIT Journal of Chemistry 2(3): 77-84.

Olaoye, O.A. 2016. Changes in physicochemical properties and volatiles of pork balangu as possible indicators of spoilage during ambient temperature storage. Journal of Food Processing and Preservation 40: 473-482. DOI: 10.1111/jfpp.12625.

Olaoye, O.A. and Dodd, C.E.R. 2010. Evaluation of bacteriocinogenic Pediococcus acidilactici as protective culture in the preservation of tsire, a traditional Nigerian stick meat. Journal of Food Safety 30: 867-888.

Olaoye, O.A. and Onilude, A.A. 2011. Quantitative estimation of antimicrobials produced by Lactic Acid Bacteria isolated from Nigerian beef bacteria. International Food Research Journal 18: 1104-1110.

Omojola, A.B. 2008. Yield and organoleptic characteristics of Suya (an intermediate moisture meat) prepared from three different muscles of a matured bull. African Journal of Biotechnology 7: 2254-2257.

Onilude, A.A., Sanni, A.I., Olaoye, O.A. and Ogunbanwo, S.T. 2002. Influence of lactic cultures on the quality attributes of tsire, a West African stick meat. World Journal of Microbiology and Biotechnology 18: 615-619.

Partidário, A.M., Padilha, M., Roseiro, C., Silva, L. and Santos, C. 2006. Volatile compounds produced during ripening of Paínho de Portalegre dry fermented sausage. Review De Ciências Vetinary 101: 115-120.

Rivas-Canedo, A., Fernández-García, E. and Nuñez, M. 2009. Volatile compounds in fresh meats subjected to high pressure processing: Effect of the packaging material. Meat Science 81: 321-32.

Ruiz, J., Ventanas, J. and Cava, R. 2001. New device for direct extraction of volatiles in solid samples using SPME. Journal of Agriculture and Food Chemistry 49: 5115-5121.

Wierda, R.L., Fletcher, G., Xu, L. and Dufour, J.P. 2006 Analysis of volatile compounds as spoilage indicators in fresh king Salmon *(Oncorhynchus tshawytscha)* during storage using SPME-GC-MS. Journal of Agriculture and Food Chemistry 54: 8480-8490.