Original Article

Mechanical extraction of shea butter: An optimisation and characterisation study with comparison to other methods of extraction

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Abstract

Shea butter (SB) production by mechanical extraction (ME) was optimized by response surface methodology. The process parameters studied (with their ranges) were sample weight (100 – 200 g), temperature (60 – 120ºC) and duration of applied pressure (10 – 30 min) to optimise the yield of SB. The characteristics of the SB were determined using standard methods and Fourier transform infrared spectroscopy. A comparative study of the SB from ME with other methods of extraction was also performed. The maximum 37% (w/w) yield of SB was obtained with 150 g sample at 90ºC and 20 min. The R² (0.9957) obtained from ANOVA showed that the quadratic model fitted the experimental data well. The characteristics of the SB from ME showed non-compromising quality, with a yield greater than with the traditional method but lower than with solvent method. This study showed that the extraction method affects both yield and quality of SB.

Keywords: shea butter, mechanical extraction, Box-Behnken, FTIR

1. Introduction

Extraction of vegetable oil is nowadays done by using chemical solvents (such as n-hexane) that give a high yield of vegetable oil with short processing time and low energy consumption. However, due to negative environmental impacts and potential health risks from using a solvent in the extraction of vegetable oil, particularly in industry scale, the method is regarded hazardous (Alenyorega, Hussein, & Adongo, 2015). Ikya, Umenger, and Iorbee (2013) further substantiate this claim, when a solvent was used to extract SB with the relatively high 47.5% yield, but with compromised characteristics appearance, texture, odour, and general acceptability.
Hence, an alternative method of extraction is needed to obtain both high yield of vegetable oil and the required quality for consumption and other use. One of the available alternative methods is mechanical extraction (ME), which is the most popular globally; it is safe and simple to use. The vegetable oil from ME has been reported to be chemical free and rich in protein. This makes ME advantageous over the more efficient solvent extraction. But the ME is relatively inefficient, leaving about 8 to 14% of the available oil in the cake (Singh & Bargale, 2000). Several efforts have been made by different researchers to improve the efficiency of ME by optimising the process parameters such as applied pressure, pressing temperature, and moisture content of the kernels. For instance, A. M. Olaniyan and K. Oje (2007a) studied the use of ME to extract SB with a 4\(^3\) factorial experimental design and obtained a maximum yield of 35.1%. Further studies by Olaniyan and Oje (2011) using a model equation with Mechanical Extraction Rig (MER) for SB gave a maximum yield of 35.39%. The yields obtained were very low compared to 60% SB present in its kernel (Axtell, Kocken, & Sandhu, 1993a). Therefore, a more robust optimisation approach, such as response surface methodology (RSM), can be employed for optimizing ME to improve the yield of SB without compromising the quality.

The RSM is a mathematical tool that employs experimental design with the ultimate goal of evaluating operating parameters for any process, using minimum numbers of experimental runs. It is widely used as a technique to optimize, develop, or improve processes. The main advantage of RSM, apart from the minimum number of experimental runs, is that it generates enough information for statistical acceptability of the results (Akinoso, Aboaba, & Olajide, 2011). The use of RSM for ME of SB is expected to improve the yield and maintain the quality. The SB vegetable oil is obtained from shea kernels.

Shea fruit includes green epicarp, mesocarp (pulp) that is fleshy, housing a hard endocarp that ultimately encloses the shea kernel (nut) known as the embryo (A. M. Olaniyan & K. Oje, 2007). The shea kernel contains about sixty percent (60%) shea butter (Axtell, Kocken, & Sandhu, 1993b), which is a major raw material for several purposes. The SB can be used as a lubricant (material for greasing, engine oil, and baking industries) and as insect repellent and protection against Simulium infection (Ajala, Aberuagba, Olaniyan, & Onifade, 2016). Shea butter is also known to contain a relatively large amount of unsaponifiable content, between 4 and 11%. The unsaponifiable compounds include triterpenes, tocopherol, phenols, and sterols, which are anti-inflammatory with antioxidant properties (F. G. Honfo, N. Akissoe, A. R. Linnemann, M. Soumanou, & M. A. J. S. Van Boekel, 2014). Therefore, SB can be used for medicinal purposes as a sedative in the treatment of sprains, dislocations, minor aches, and pains; unguent for skin; and as an antimicrobial agent promoting the rapid healing of wounds (Ajala et al., 2016). The SB consists of more than 90% triglycerides, comprising more than 50% unsaturated fatty acids (oleic, stearic, linoleic and palmitic fatty acids) that are prone to oxidation (F.G. Honfo et al., 2014). The presence of high amounts of unsaturated fatty acids in the SB causes oxidative degradation of the butter, whether made by traditional extraction or any other extraction procedure that involves boiling or improper processing or storage. This leads to inconsistent quality and limited shelf-life (Lovett, 2004; Masters, Yidana, & Lovett, 2004). The oxidative degradation of SB degrades the edibility of the butter, produces sensory and chemical changes, and reduces the nutritional values (Nahm, Juliani, & Simon, 2012). This has motivated a lot of interest in SB extraction and characterisation. Hence there is a need to compare alternative extraction processes, as this choice affects the yield and quality of the SB.

This study, therefore, optimised SB extraction by ME using RSM. Comparative study of extracted SB from mechanical (SBM), SB from traditional (SBT), SB from solvent (SBS) and SB from enzymatic (SBE) extraction methods was performed, assessing yield, physicochemical properties, and functional groups.

2. Materials and Methods

2.1 Materials

Shea kernels (Sk) were purchased from Ilorin South, Kwara State, Nigeria. The Mechanical Extraction Rig (MER) that was used in this study comprised two sections. The first section was the Hydraulic Press Machine (HPM) with 10 MPa capacity, model number MS50 - 50 KN (Testometric Co Ltd., UK). The second section was a mechanical expression rig, shown in Plate 1 and Figure 1, which was developed by A. M. Olaniyan and K. Oje (2007a). This mechanical expression rig was used in this study to extract shea butter from shea fruit kernels.

![Plate 1. Mechanical expression rig.](image)

2.2 Methods

2.2.1 Box-Behnken (BB) design with quadratic model in response surface methodology (RSM)

The quadratic model is an empirical model that involves a second-order polynomial, and the BB experimental design was employed in this study. The model was fit to experimental data to predict the yield from independent manipulated factors, and was used to maximize the yield by determining the optimal operating conditions for SB extraction. The model is as shown in Equation 1:

\[ Y = \beta_0 + \sum_{i=1}^n \beta_i x_i + \sum_{i=1}^n \sum_{j=i+1}^n \beta_{ij} x_i x_j + \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} x_i x_j + \epsilon \]

Here Y represents the predicted response; \( \beta_0 \) is the offset term; \( \beta_i \) are the linear coefficients, and \( \beta_{ij} \) are the interaction coefficients, while \( x_j \) are the independent variables (factors).

The BB design of RSM is incorporated into the Design Expert software (version 8) and was used to design the experiments in this study. The empirical results from designed experiments were provided to the software for analysis, which generated predictive models. The model was further subjected to optimization using the same software, with the yield of SB as the objective function to be maximized, and the process parameters (factors in the experimental design) constrained within prescribed limits. Statistical analysis was also carried out through RSM using the Design Expert. The regression coefficients and significant model terms in the regression model, as well as optimal factor level for maximal yield of SB, were obtained.

1) Experimental design for mechanical extraction

The BB design of Design Expert was used in an optimization study of the extraction of SB. The three process parameters investigated were sample weight (100 – 200 g), temperature (60 – 120°C) and duration of applied pressure (10 - 30 min). The ranges chosen for these parameters were obtained from a preliminary investigation, and are shown in Table 1 along with the seventeen experimental runs.

2) Experimental procedure for mechanical extraction

The Sk were ground into small particles and sieved using a mesh to obtain <2.06 mm particle size. The sieved sample size (100, 150 or 200 g) was weighed and poured into press cage cylinder.

The sample in the cylinder was heated with the aid of a temperature-controlled heater band at desired temperature (60, 90 or 120°C) for the duration of 30 min. Thereafter, the sample was compressed by the HPM by the compression piston at a pressure of 8 MPa for a chosen period of time (10, 20 or 30 min).

The SB extracted was collected in the output pan and was weighed to determine the yield using Equation 2.

\[ \%\text{yield} = \frac{\text{weight of oil extracted}}{\text{weight of shea kernel used}} \times 100 \]
2.2.2 Characterisation of SBM

1) Physical and chemical properties

The physical and chemical properties of the SB were determined using official methods of analysis (AOAC, 1998). The properties determined were saponification value, free fatty acid, acid value, iodine value, viscosity, peroxide values, pH and melting point. The Rudolph Research Analytical (RRA) DDM 2911 Automatic Digital Density Meter was used to determine the relative density (Ajala et al., 2016).

2) FTIR

The Bruker ALPHA FT-IR spectrometer was used for the FTIR analysis of the extracted SB, in the range of 400–400 cm⁻¹ (Ajala et al., 2016).

3. Results and Discussion

3.1 Statistical analysis of the mechanical extraction of shea butter

The %yield of SB from ME in the experiments by the BB design of RSM is shown in Table 2. The ANOVA for fitting the second-order response surface model by least squares is shown in Table 3. From the table, the p < 0.0001 of the model demonstrates high significance of the model in predicting the response and suitability of the deduced model. The high F value of the model (180.98) with a very low p-value (<0.0001) shows that the model is highly significant. The significance of all the coefficients is established by p – values shown in Table 3.

The second order terms in the three variables considered were statistically significant, each of them having p < 0.0005. Also, the low CV (1.22%) shows that the results of the model are reliable. The quality of the model is shown by R² = 0.9957, which indicates that 99% of the experimental variation was explained by the predictive model. The high Adj. R² (0.9902) also supports the significance of the model, while the high value of predicted R² (0.9324) indicates reasonable precision of the fitted model.

3.2 Effect of process variables on the yield of SB from ME

The effect of sample weight and temperature on the %yield of SB is shown in Figure 2a. This Figure shows that sample weight of 150 g at 90°C gave the maximum yield of 37% (w/w) SB. It was observed that as sample weight and temperature deviate from the centre, the yield of SB decreases. Figure 2b shows a plot of sample weight and duration of applied pressure vs. yield of SB.

From the plot, the sample weight of 150 g and applied pressure of 8 MPa for 20 min gave the maximum 37% (w/w) yield of SB and deviation of the two variables from the centre causes a decrease in the yield. The interaction between the sample weight and duration of applied pressure was significant to the yield. The interaction between duration of applied pressure and temperature is also shown in Figure 2c. The Figure reveals that the centre point in this plot at a fixed sample weight of 150 g gives the maximum 36% yield of SB. The interactions show similar trends in Figs. 2b and 2c. The results show that the maximum 37% (w/w) yield of SB was obtained with sample weight 150 g, temperature 90°C and duration of applied pressure 20 min, which is similar to the report of Olaniyan and Oje (2011), where heating temperature, applied pressure and loading rate of 82.24°C, 9.69 MPa and 2.50 mm min⁻¹, respectively, gave the maximum 35.39% yield of SB in a 4² factorial experimental design.

Mohagir, Bup, Abi, Kamga, and Kapseu (2015) obtained a better yield of 45.7% SB than this study, when RSM with Doehlert experimental design was used for the optimisation of kernel preparation conditions before press extraction of SB. However, the roasting temperature (160-225°C) used by Mohagir et al. (2015) was rather too high and may have affected the quality of the SB produced.

3.3 Optimisation of mechanical extraction of shea butter

The coefficients of the response surface model for ME of SB as provided by Equation 3 were evaluated. The optimal variables that gave maximum percentage yield of SB for ME were obtained by using the regression fit, in the Design Expert software.

\[
\text{Oil Yield } (\%) = -51.66250 + 0.2106 \times A + 1.46537 \times B + 0.50395 \times C + 3.64667 \times D - 0.05 \times A \times B - 1.30000 \times B \times C - 3.50000 \times C \times D - 0.04 \times C \times B^2 - 0.01200 \times C^2
\]

The optimum was found at sample weight 154.67 g, temperature 92.49°C and duration of applied pressure 19.97 min, with an optimal 37% (w/w) yield of SB. Experiments were carried out to validate the model predictions, at the model predicted optimal settings, and the yield of SB obtained was 36.87% (w/w). Thus, the verification experiments confirmed validity of the predictive model. The error between the predicted and the validated result was 0.353, which is low, and within the limits (0–5%) of allowable error, and this result indicates good reproducibility of the experiments. This shows that the model predictions are in good agreement with the experimental results.

### Table 2. Percentage yield of SB obtained from different methods of extraction.

<table>
<thead>
<tr>
<th>Extraction Method</th>
<th>% Yield</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>Akingbala et al. (2006)</td>
<td>(a) 27.2</td>
</tr>
<tr>
<td></td>
<td>Coulibaly et al. (2009)</td>
<td>(b) 28</td>
</tr>
<tr>
<td></td>
<td>Ilyka et al. (2013)</td>
<td>(c) 34.1</td>
</tr>
<tr>
<td>Solvent</td>
<td>Ilyka et al. (2013)</td>
<td>(a) 47.5</td>
</tr>
<tr>
<td></td>
<td>Nkouam et al. (2007)</td>
<td>(b) 53.77</td>
</tr>
<tr>
<td></td>
<td>Ajala et al. (2015b)</td>
<td>(c) 66.90</td>
</tr>
<tr>
<td>Supercritical CO₂</td>
<td>Nkouam et al. (2007)</td>
<td>39.57</td>
</tr>
<tr>
<td>Enzymatic</td>
<td>Ajala et al. (2015a)</td>
<td>42.95</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Akingbala et al. (2006)</td>
<td>(a) 24.0</td>
</tr>
<tr>
<td></td>
<td>Olaniyan and Oje (2011)</td>
<td>(b) 35.90</td>
</tr>
<tr>
<td></td>
<td>This study</td>
<td>(c) 37</td>
</tr>
</tbody>
</table>
Table 3. Physico-chemical properties of SBT, SBS, SBM, and SBE.

<table>
<thead>
<tr>
<th>Properties</th>
<th>SBT</th>
<th>SBS</th>
<th>SBM</th>
<th>SBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Density</td>
<td>0.908</td>
<td>0.851</td>
<td>0.931</td>
<td>0.912</td>
</tr>
<tr>
<td>Kinematic Viscosity (mm²/s⁻¹)</td>
<td>30.68</td>
<td>44.84</td>
<td>19.72</td>
<td>26.57</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>33.0</td>
<td>40.5</td>
<td>30.0</td>
<td>37.5</td>
</tr>
<tr>
<td>Free fatty acid (%)</td>
<td>9.0</td>
<td>23.89</td>
<td>6.85</td>
<td>8.10</td>
</tr>
<tr>
<td>Acid value (mgKOH/g oil)</td>
<td>21.85</td>
<td>48.63</td>
<td>13.21</td>
<td>18.39</td>
</tr>
<tr>
<td>Peroxide value (meq O₂/kg)</td>
<td>9.80</td>
<td>11.00</td>
<td>12.10</td>
<td>13.80</td>
</tr>
<tr>
<td>Iodine value (gI/100 g oil)</td>
<td>61.90</td>
<td>70.30</td>
<td>67.28</td>
<td>58.50</td>
</tr>
<tr>
<td>Saponification (mgKOH/g oil)</td>
<td>208.00</td>
<td>202.9</td>
<td>193.90</td>
<td>180.20</td>
</tr>
<tr>
<td>pH value</td>
<td>6.09</td>
<td>5.02</td>
<td>5.53</td>
<td>5.38</td>
</tr>
<tr>
<td>Sources</td>
<td>Ajala et al., 2015b</td>
<td>Ajala et al., 2015a</td>
<td>This Study</td>
<td></td>
</tr>
</tbody>
</table>

These studies have clearly demonstrated the applicability and reliability of RSM for the optimisation of extraction variables in SB extraction using ME method.

3.4 Comparative analysis of SB from ME with other methods of extraction

3.4.1 Percentage yield of SBM

Table 4 shows the yield of SB obtained with different methods of extraction. The table shows that the maximum yield obtainable for SB was with solvent extraction, as reported by Ajala et al. (2016) (66.90% (w/w)) and Iya et al. (2013) (47.5%). Nkouam, Kapseu, Barth, Dirand, and Tchatchueng (2007) corroborate the fact that solvent extraction of SB gave higher yield (53.77%) than even supercritical CO₂ methods (39.57%, w/w). The maximum yield for mechanical extraction of SB was 35.90% (Olaniyan & Oje, 2011) and that of enzymatic extraction was 42.9% (Ajala, Aberuagba, Olaniyan, & Oje, 2017). This study found 37% SB (w/w) yield, which clearly shows that mechanical extraction could not yield over 40% SB. However, the yield of ME (37% SB) was more than that of by traditional extraction as in Akingbala, Falade, Adebesi, Baccus-Taylor, and Lambert (2006) and Coulibaly, Ouedraogo, and Niculescu (2009), who reported 27 and 28% yields of SB, respectively.

3.4.2 Physico-chemical properties

Table 3 shows the physicochemical properties of SBM as compared with other samples of SB from other extraction methods.

3.4.3 Relative density and kinematic viscosity (mPa.s)

The relative density (RD) of SBM is 0.912 (Table 3); an indication that the RD of the SBM is relatively high compared to SBT (0.908) and SBS (0.851) but lower than SBE (0.931) as shown in Table 3.

This may be as a result of fine particles and impurities present in the SBM after gravitational settling. That RD of SBM falls between 0.870 and 0.917 was reported by A. M. Olaniyan and K. Oje (2007a), similar to the result of Hee (2011).

The kinematic viscosity (Kv) was 26.57 for SBM (Table 3). The Kv of SBM is the lowest among SBT and SBS.
as shown in Table 3, and lower than 80 obtained by A. M. Olaniany and K. Oje (2007a), but greater than of SBE (Table 3). The difference in these results may be due to a temperature differences in the extraction process (A. M. Olaniany & K. Oje, 2007b). The SBE is the least viscous among the samples, which may be due to the presence of water in the extraction process.

### 3.4.4 Melting point

The melting point (mp) of SBM is 37.5°C which falls within the 20 - 45°C range reported by F. G. Honfo, N. Akiisoe, A. R. Linnemann, M. Soumanou, and M. A. J. S. Van Boekel (2014). This value is similar to the 37.0°C obtained by A. M. Olaniany and K. Oje (2007b) and close to the human body temperature, hence suitable for different purposes such as a base for ointment (Ajala et al., 2016). Comparatively, as shown in Table 3, the mp of SBE is the lowest, followed by SBT. This might be due to the presence of water and/or impurities in the extraction process of SBE. The mp of SBM is a little lower than of SBS. The lower mp might be due to the hydrolysis of triacylglycerols and oxidation of unsaturated fatty acids, as a result of heating for 30 min (Gunstone, 2004; O'Brien, 2009).

The mp of SBM is also closer to that of cocoa butter (32 - 35°C), therefore SBM can be recommended as a substitute for the more expensive cocoa butter in the production of confectioneries (Akingbala et al., 2006).

### 3.4.5 Acid value and free fatty acid

The acid value (Av) of SBM is 18.39 mgKOH/g, which falls within the range 0 - 21.2 mgKOH/g reported by F. G. Honfo et al. (2014) and Nkouam et al. (2007). However, the SBM is lower than the 47.7 mgKOH/g reported by A. M. Olaniany and K. Oje (2007b). In the comparison with previous studies shown in Table 3, SBM acid value is the lowest among SBT and SBS, but slightly higher than that of SBE. This indicates that SBM and SBE are in good condition and edible with long shelf life; and suitable for industrial uses such as paint making, cosmetics and food applications, compared to the other two (Nitiéma-Yefanova, Poupaert, Mignolet, Nebié, & Bonzi-Coulbaly, 2012). This is because Av of vegetable seeds increases with storage duration depending on the conditions (Hee, 2011; F. G. Honfo et al., 2014).

The FFA value of SBM is 8.10% which is the lowest among those of SBT and SBS, but higher than that of SBE, as shown in Table 3. This shows that SBM is the best among SBT and SBS. However, SB with FFA>1% is not suitable for biodiesel production, and not good for cosmetic and food uses due to irritation of tongue and throat (Ajala et al., 2016), but rather it can be used as a lubricant, because of the inherent lubricating properties. The FFA of SB from all the methods of extraction analysed was >1%; this may be due to the hydrolysis of triglycerides caused by the lipolytic activity of the fruit lipase and microorganisms (Nitiéma-Yefanova et al., 2012).

### 3.4.6 Peroxide value

Peroxide value (Pv) is a measure of the extent to which rancidity reactions occur during storage and measures the first product of oxidation of unsaturated fats and oils. In cosmetics and food industries, the recommended value of Pv for any vegetable oil is <10 mEq O₂/kg (F. G. Honfo et al., 2014).

The Pv of SBM is 13.80 mEq O₂/kg which slightly exceeds the recommended level (<10). However, it is within the range from 0.5 to 29.5 mEq O₂/kg reported by Dandjouma, Adjia, Kameni, and Tchiegang (2009); (Njoku, Enene, Ononogbu, & Adikwu, 2000). Table 3 shows that SBM has the highest Pv, but lower than 44.9 mEq O₂/kg observed by A. M. Olaniany and K. Oje (2007b). This might be due to the processing conditions (Hee, 2011), as the activation of lipases and tocopherol of natural antioxidants occurs with heating for 30 min at 90°C (Akingbala et al., 2006).

### 3.4.7 Iodine value

The iodine value (Iv) for SBM (58.50 g I₂/100 g oil) and the other cases are shown in Table 3. From the table, the Iv of SBM is the lowest among the cases, and also lower than 82.1 g I₂/100 g oil obtained by A. M. Olaniany and K. Oje (2007b), but higher than the 50.2 g I₂/100 g oil observed by Akingbala et al. (2006). The differences in the Iv may be due to the processing conditions or the extraction approach. These results showed that SBM is less saturated, with a lower degree of saponification and longer shelf-life than the others (Ajala et al., 2016).

### 3.4.8 Saponification value

The saponification value (Sv) for SBM is 180.2 mgKOH/g oil (Table 3) and it is within the acceptable range
188 - 190.5 mgKOH/g oil (Akingbala et al., 2006). Table 3 also shows the Sv for SBT, SBS, and SBE, and it was seen that SBT has the lowest Sv which is also lower than 261.3 mgKOH/g oil obtained by (A. M. Olaniyan & K. Oje, 2007a). The reason may be due to the 90°C press temperature with 30 min heating, as the temperature is inversely proportional to Sv (A. M. Olaniyan & K. Oje, 2007a).

3.4.9 pH value

The pH of SBM is 5.38 (Table 3). The pH values show that SBM is acidic, though less acidic than SBS but more acidic than SBE (Table 3). The acidity in the SB is due to the unsaturated fatty acids (Nwabanne, 2012). Generally, the physicochemical properties of SBM observed in this study may be affected by the experimental procedures, as well as quality and pre-treatment of the kernels before crushing, as was reported by Coulibaly et al. (2009).

3.4.10 FTIR analysis

Figure 3 shows the FT-IR spectra of the various samples of SB under study, but no significant differences were noticed among the spectra. Table 4 gives the chemical compositions shown by the spectra, using relevant information available in the literature (Pandurangan, Murugesan, & Gajjivaradhan, 2014; Poiana et al., 2012; Vlachos et al., 2006). In the hydrogen’s stretching region, the signal was observed at 2918.74 and 2852.03 for SBM; an indication of symmetric and asymmetric stretching vibrations of the aliphatic CH2 group. A similar signal was observed for the other samples. In the second region of double bond’s stretching, the band at 1741.30 is seen; an indication of ester carbonyl functional group. In all the results, a higher 37% yield of SB than the traditional extraction method of extraction may not have a significant effect on the functional groups. In all the results shown, C=C was absent; this corroborates the iodine and peroxide values obtained. The low iodine values (<100mgI2) show that the SBM and the other samples are saturated, while the low peroxide values that show deterioration of the samples; an indication that the shelf-life is longer than cases with unsaturated C=C bonds.

4. Conclusions

The maximal ME yield was 37% SB at the optimal choices of sample weight (154.67 g), temperature (92.49°C) and duration of applied pressure (19.97 min). This study concluded that RSM was not able to dramatically improve the yield of SB from ME as the 37% yield obtained in this work did not much improve the literature reported 35% SB yield. SBT has shown higher yield of SB. In a comparison of four methods of extraction, solvent extraction gave the highest yield of SB. However, the ME is more environmentally friendly, easy to use, and more suitable for SB extraction than the other methods. The physicochemical properties of SB obtained by ME showed superior quality among the SB extraction methods tested. The FTIR analysis showed no significant differences between the different methods of extraction. The study concludes that the ME gave a higher 37% yield of SB than the traditional extraction method with 28% yield, while the solvent (66.9%) SB and enzymatic (43% SB) extraction methods had even higher yields. This study revealed that the method of extracting SB can significantly affect yield and characteristic quality of the butter.

References


