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Effect of soil variation on quality of shea butter in selected areas of the northern region of Ghana

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Soil variation and its effect on the physical and chemical properties of shea butter, a product from the nut of the shea tree, were investigated in four districts of the northern region of Ghana. Thirty-six samples of freshly extracted shea butter together with 36 soil samples were collected and stored at 25°C for analysis. Clinical analysis of soil properties and the clinical analysis of the physical and chemical properties of shea butter were investigated using standard methods. The results showed that the soil organic matter (1.78%), soil organic carbon (1.03%), soil nitrogen (0.10%) and sandy soil have significant positive impact on the fat content (48.69%) of the shea kernel, and the soil cation exchange capacity (6.61%) has a negative effect. Soil properties do not have an impact on the chemical properties of the shea butter. This study thus concludes that apart from other factors such as the method adopted for the extraction of shea butter, soil composition contributes significantly to the quantity of shea butter extracted from the shea kernels.

Key words: Physical, chemical, soil quality, shea butter, fatty acids, vegetation, climate.

INTRODUCTION

The extraction of shea butter is a traditional activity for the people of northern Ghana. The shea butter extraction activity begins with the picking of the shea fruits from the wild or on farms and it is seasonal. Several factors, including the moisture content of the kernel, the various pretreatment of the shea kernel and the kneading session, can affect the quality of the generated shea butter.

There are many different approaches of shea butter extraction. In recent times, the technologies that have been reported include the traditional extraction method, mechanical extraction technology and chemical and biological extraction methods (USAID, 2004). Each of these methods has shown an influence on the quantitative and qualitative parameters of the shea butter (Abdul-Mumeen, 2013). Frank et al. (2007) attributed the variation of the fatty acid composition of the butter to its geographical source. What has not been well examined is whether soil composition has an influence on the chemical and physical properties of shea butter.

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Table 1. Sample collection sites and number of samples collected.

Distinct/municipal/ Metropolis	Sampling site	Number of samples	
		Soil	Shea butter
Yendi Municipal	Yendi	9	9
Nanumba North	Bimbilla	9	9
Savelugu-Nanton	Savelugu	9	9
Tolon	Tolon	9	9
Total		**36**	**36**

Shea trees are relatively highly adaptable as reflected by their wide geographical distribution. They are not adaptable to lands vulnerable to flooding (Agyente and Kwame, 2010), but can thrive well on dry sandy soil that have a good humus cover. They can survive on a variety of other soil types as well (Hall et al., 1996). They have extensive, relatively shallow root system which helps them to tolerate extended dry seasons that can last up to 8 months as well as the occasional drought characterizing savannah zone (Vermilye, 2004). In fruit tree like shea tree, nutrient imbalances may manifest themselves in the quality characteristics of the fruit and its products or otherwise.

Different soil types have different nutrient levels which are blended together in differing amounts to determine the type of soil. Thus soil is considered as a complex natural material derived from weathering of rocks and decomposition of organic materials which provide nutrients, moisture and anchorage for plants (Manjula, 2009). Soil physical factors, especially soil structure, texture aeration and moisture as well as soil micro-organisms have a major influence on plant growth and root development. Soil chemical factors like pH, nutrient availability and cation exchange capacity also greatly influence plant growth.

A well textured and structured soil would have the correct percentage of sand, silt and clay which is arranged together in the correct manner to allow aeration, drainage and microbial activity to occur. Nutrient availability varies from one environment to another. At some levels nutrients could be deficient and at other levels it is high (www.landscapeinfoguid.com.au). The cation exchange capacity (CEC) for instance**,** measures the extent to which soil can hold and exchange plant nutrients. The ability of soil to hold positively charged nutrients from being leached and lost from soil is important to maintaining soil fertility. Clay and organic matter have a negative charge. They allow the soil to hold these nutrient cations due to the attraction of charges. Soils with high clay or organic matter content will have a higher CEC. Sandy soils tend to have a lower CEC. Shea tree parklands which occur in the different environments would have unbalanced nutrients availability. This infact could affect their yield and the quality of their products. The current study examines the effect of soil variation on the properties of shea butter in four shea growing districts of Ghana.

METHODOLOGY

Sampling

Soil and shea nuts samples were collected from four districts in the Northern Region of Ghana. Three separate shea tree parklands were identified in each district and within each of the parkland thirty soil samples were randomly collected at the depth of 15 cm using an auger. The samples collected were bulked together and mixed thoroughly. Nine homogenous mixtures were obtained for each district. In all 36 soil samples (nine from each of the selected districts) were sent to the laboratory for analysis.

In addition, shea nuts fruits were also collected from each of the identified shea tree parklands from the four districts. The fruit nuts were processed into shea butter using the traditional method as describe by Olaniyan and Oje (2007) and nine samples from each of the four districts were taken and kept in plastic containers, labeled and transported to the laboratory for analysis. All the thirty six (36) shea butter samples were taken for laboratory analyses. Information about sample number and location is shown in Table 1.

Analysis of soil physical and chemical parameters

The laboratory analysis was carried out at the Savana Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR), Nyankpala in the Northern Region of Ghana. The soil physical and chemical properties that are tested in this research were: The pH and the particle size distribution, the level of nitrogen and organic carbon content, phosphorus levels, potassium levels and cation exchange capacity.

Pre-treatment of soil for physical and chemical analysis

The soil samples were air-dried in a shallow tray placed in a well ventilated area. Clay clods were broken and soil lumps crushed such that the gravel, roots and organic residues became separated. The crushed soil samples were screened through a 2 mm sieve to very fine soil.

Determination of soil pH

Ten gram air-dried soil sample was weighed into a 100 ml beaker. Twenty-five milliliter distilled water was added and the suspension stirred vigorously for 20 min. The suspension was allowed to stand for about 30 min for the suspended clay to settle out from the suspension. The pH meter was calibrated with pH buffer 4, 7 and 11. The electrode of the pH meter was inserted into the partly settled suspension. The pH value was then read and recorded.

Determination of soil particle size distribution

Hydrometer method as described by Brian (1997) was used for this analysis.

Determination of phosphorous

The available phosphorus was determined according to the procedure adopted by Bray and Kurtz (1945).

Organic carbon determination

The method employed for this analysis was based on the procedure used by Walkley and Black (1935).

The procedure for determining the CEC

Sodium acetate method was employed for this analysis. Five grams (5 g) of the soil sample was accurately weighed and transferred into a 50-ml centrifuge tube. Twenty-five milliliter (25 ml) of 1.0 M $CH_3CHOONa$ solution was added. The content was shaken in a mechanical shaker for 5 min. This was centrifuged at 2000 rpm for 5 min. The liquid was decanted off and the extraction process repeated for three more times. The sample was washed with the same extraction process using isopropyl alcohol followed by the use of ammonium acetate solution. Decant was collected into a 100-ml volumetric flask fitted with a funnel and filter paper. This was made up to volume with ammonium acetate solution. The sodium concentration was estimated by flame photometer and the result expressed in meq/100 g of the dry soil. The measured Na expressed in meq/100 g of soil is actually the cation exchange capacity of the soil (Motsara and Roy, 2008).

Nitrogen analysis

The Kjeldahl method by AOAC (1997) was used for the analysis.

Analysis of potassium in the soil sample

The potassium content was determined using ammonium acetate method as prescribed by Toth and Prince (1949).

Analysis of shea butter physicochemical properties

The butter was extracted by the traditional method. The physicochemical properties considered for analysis included; pH, fat content, colour, moisture content, insoluble impurities, free fatty acids, iodine value, peroxide value, saponification value, ester value, unsaponifiable value and specific gravity.

Determination of pH of the shea butter

The HI electronic meter as adopted and used by Akpan et al. (2006) was employed for this analysis.

Determination of fat content of the shea butter

The fat content of the butter was determined by the method recommend by Sergers (1990). Soxtherm analyzer was used for the analysis.

Shea butter colour determination

The shea butter sample was melted at 30°C in water bath. It was then placed in a cuvette and the colour measured using Tintometer a model recommended by AOAC (1997).

Determination of shea butter specific gravity (SG)

The SG of the shea butter was determined using the method proposed by Akpan et al. (2006).

Determination of refractive index of shea butter

The refractive index was determined using Abbey refractometer, a procedure recommended by AOCA (1997).

Determination of the moisture content of the shea butter

Fifty grams (50 g) of cleaned shea butter sample was weighed and dried in an oven at 50°C. After every 1 h, the sample was removed from the oven and placed in the desiccator for 30 min to cool. It was then removed and weighed according to Akpan et al. (2006). The percentage moisture in the butter was then calculated from:

$$\text{Moisture\%} = \frac{100(W_1 - W_2)}{W_1}$$

Where; W1 = Original weight of sample before drying (g), and W2 = Weight of sample after drying (g).

Determination of insoluble impurities of the shea butter

The insoluble impurities were determined using the IUPAC 2.604 method as described in Hee (2011).

Determination of free fatty acid

The free fatty acid was determined using the standard method in Akpan et al. (2006).

Saponification value determination

The saponification value was determined using titremetric method discussed by Pearson (1976).

Determination of unsaponifiable matter

The unsaponifiable matter of the shea butter sample was determined according to IUPAC 2.401diethyl ether method (Paquot,

Table 2. Shea butter physical properties.

District	RI	SG	%Red	%Yellow	% Fats	% Moisture	% Impurities
Tolon	1.47	0.91	2.35	60.00	48.24	5.31	0.14
Yendi	1.47	0.91	4.00	70.00	49.37	6.65	0.09
Savelugu	1.47	0.91	2.15	33.00	48.78	4.81	0.27
N'ba North	1.47	0.91	3.55	59.00	48.38	4.70	0.03
Mean value	1.47	0.91	3.01	55.50	48.69	5.37	0.13
P-value	*	*	0.007	0.006	0.001	0.001	0.081

*Means were all of the same value, SG and RI stand for specific gravity and refractive index respectively.

1987).

Peroxide value determination

Peroxide value was determined according to Atinafu and Bedemo (2011).

Iodine value determination

Iodine value of the sample was determined using the official method described by AOAC (1997).

Determination of ester value

The ester value was determined using the procedure described by Dileesh (2009-2012), and Lubrizol procedure (2013). Ester values were determined using the relation: Ester value = acid value – saponification value.

Statistical analysis

Data generated from the various laboratory activities were subjected to the ANOVA procedure using the Minitab 15 (2000 version) software. Significant differences were read at 5% significant level. Where necessary, pair-wise comparisons were made where differences were significant using the Fisher's LSD. MS Excel (2007) was used to draw the graph.

RESULTS AND DISCUSSION

The recovery of shea butter from the nut was based on the traditional extraction concept. The physicochemical properties of soil from four districts of Northern Ghana showed significant influence on the fat content of shea butter. The shea butter (fat content) was significantly ($P \leq 0.05$) different from one district to the other as elaborated in Table 2. The fat content of the shea butter varied greatly from the lowest of 48.24% at Tolon to the highest of 49.37% at Yendiacross the four shea butter producing districts. The mean butter yield was 48.69%. Although the volume of butter yield at the Yendi Municipality could have been influenced by the amount of moisture (6.65%) remaining in the butter the fat content (49.37%), soil carbon (1.18%), organic matter (2.04%) and soil nitrogen (0.10%) were all highest at Yendi Municipality and least (48.24, 0.85, 1.46 and 0.08% respectively) at the Tolon district. What this observation could mean is that soils within the Yendi Municipality are richer in plant nutrients, especially nitrogen and organic matter, than the other districts. Moreover, nitrogen is combined in stable organic matter that decomposes very slowly and about 2,000 to 6,000 lb/a of organic nitrogen are generally found in soils (Bundy, 1998). This explains why the Yendi Municipality which has the highest organic matter content also contains the highest amount of nitrogen (Table 4) even though the nitrogen content of soils across the four districts in the current study was generally low (<0.12%). But formation of fats in seeds and fruits occurs late in the ripening process. Sugars and starches predominate in fruits, seeds, and sap in the unripe condition. These apparently are converted by enzymes during the maturing process to fatty acids and glycerol, which then form glycerides (www.britannica.com/synthesis and metabolism). Thus, unripe shea nut fruits or poor quality shea kernels will also produce low fat content.

The yellow colour intensity presented in Table 2 varied significantly among samples across the four districts. The yellow colour intensity ranged from a minimum of 33.0% in the Savelugu district and a maximum value of 70% at the Yendi Municipality. The yellow colour intensity was statistically different ($p \leq 0.05$) across the districts. Shea butter produced in the northern regions of Ghana is a whitish–yellow substance by visual examination. The colour can however be manipulated to golden through the addition of roots of some plants such as *Cochlospermum planchonii* (Agyente and Kwame, 2010). The other detected colour was the red colour which ranged from 2.15 to 4.00% with a mean percentage of 3.01. Soil characteristics across the four shea producing districts did not show any direct relationship with the colour of the shea butter. Thus, soil chemical and physical properties have no impact on the colour of shea butter. This supports Omujal (2009) assertion that the colour of oil is genetic, it comes from the natural colouring matters such as α- carotene, β-

Table 3. Shea butter chemical properties (mg/Kg).

District	Free fatty acid	Acid value	Butter pH	Peroxide value	Iodine value	Ester value	Saponification value	Unsaponifiable value
Tolon	5.31	10.61	5.40	9.29	60.66	174.97	185.57	3.60
Yendi	7.67	15.35	4.70	9.49	63.73	165.91	181.59	3.34
Savelugu	3.49	6.97	4.80	6.35	55.06	178.55	185.75	4.26
N’ba North	5.05	10.11	5.80	7.10	58.32	176.96	187.07	5.27
Mean value	5.37	10.76	5.18	8.06	59.44	174.10	185.00	4.12
P-value	0.008	0.008	0.001	0.002	0.001	0.001	0.001	0.002

carotene and xanthophylls which already are inherent traits in plants.

The moisture content presented in Table 2 was significantly different (P ≤ 0.05) across the four shea butter processing districts. The least of 4.7% was recorded at the Nanumba North district and the highest of 6.7% at the Yendi Municipality. The mean moisture content of the shea butter by the findings of this research was 5.37%. The minimum moisture content (4.70%) was recorded at Nanumba North district and the maximum moisture content was found in shea butter from the Yendi Municipality as shown in Table 2. Soil properties by all estimation have no effect on the moisture content of shea butter. One would have predicted the soil with the highest water holding capacity; clayey (highest at Tolon) would have an influence on the moisture content. On the contrary, shea butter moisture content (Table 2) and percentage clayey soil have no direct relationship. Meanwhile moisture is a chemical contaminant which is usually well mixed with oil and significant amount of moisture in oil support microbial growth (Alirezalu et al., 2011) and lipid oxidation leading to rancidity (Hee, 2011) and thereby reducing the shelf life of the shea butter. Low moisture content indicates good quality butter (Olaniyan and Oje, 2007) and the minimum shea butter moisture level is 5.23% (Quainoo, 2012) which is higher than the findings (4.70%) of this research. Per the West African Regional Standards (RTC, 2006) shea butter with moisture range of 0 to 2.0%can be used in the cosmetic, pharmaceutical, food and soap making industries. The moisture content by our findings is between 4.70 and 6.65% and thus shea butter from the four districts will need further drying to be used in these industries.

The statistical analysis of the shea butter impurities indicated that the impurities were not different (P ≥ 0.05) across the various districts. The butter impurities ranged from 0.03% at Nanumba North District to 0.27% at Savelugu district. The shea butter from all four districts had uniform specific gravity (density) as shown in Table 2. Shea butter insoluble impurities were statistically the same across the shea producing districts. Insoluble impurities generally do not have any direct relationship with soil properties. They normally get into the shea butter through processing and handling of the shea butter from the production centre to the end user. The findings of this research suggest that the shea butter from the Savelugu district is the most contaminated with insoluble impurities andNanumba North is the least contaminated. Hamilton and Rossell (1986) and Hee (2011) agree that insoluble impurities in shea butter refer to dirt and other foreign materials. Shea butter from the Nanumba North district and the Yendi Municipality can be classified under Grade 1 (Table 3) due to their low levels of insoluble impurities (0.03 and 0.09 respectively) as shown in Table 2. The rest are classified under Grade 2 (Table 3) and what this means is that per the insoluble impurities shea butter from the Nanumba North district and the Yendi Municipality are suitable for use in cosmetic and pharmaceutical industries as well as for direct consumption. Shea butter from Tolon and Savelugu are suitable for the food industry; for manufacturing chocolate, edible oil, confectionaries and margarine.

The chemical properties of shea butter tested under this study: free fatty acids, acid value, butter pH, peroxide value, iodine value, saponification value, ester value and unsaponifiable value were shown in Table 3. They did not show any specific correlation to the soil chemical and physical properties.

Analysis of the soil particle size shows that the sandy soil dominates the shea growing district as shown in Figure 1. The sandy soil was very common at the Nanumba North district but not at the Tolon district. Silt was highest at the Tolon District and least at the Nanumba North District as shown in Figure 1. Silt soil is the second most common soil in the shea butter producing communities (Figure 1). The least common soil in shea butter producing communities according to this study is the clayey soil (Figure 1). Clayey soil was common in the Tolon District but not at the Savelugu-Nantong District. The findings of this research supports conclusions by Hall et al. (1996) that Shea trees thrive well on dry sandy soils that have good humus cover.

The statistical analysis of the soil exchange potassium indicated that the percentage exchange potassium were all different (P ≤ 0.05) across the various districts. The exchange potassium values ranged from 0.16 at the

Table 4. Percentage soil chemical properties across four shea districts of Ghana.

District	% OC	% OM	%CEC	% Total nitrogen	% Phosphorus	% Exchange potassium
Tolon	0.85	1.46	7.03	0.08[a]	2.49	0.23
Yendi	1.18	2.04	6.25	0.10[b]	2.89	0.16
Savelugu	1.08	1.86	6.31	0.10[b]	4.31	0.24
N'ba North	1.01	1.75	6.83	0.10[b]	2.94	0.17
Mean value	1.03	1.78	6.61	0.10	3.16	0.20
P-value	0.001	0.001	0.002	0.001	0.001	0.001

OC, organic carbon; OM, organic matter; CEC, cation exchange content.

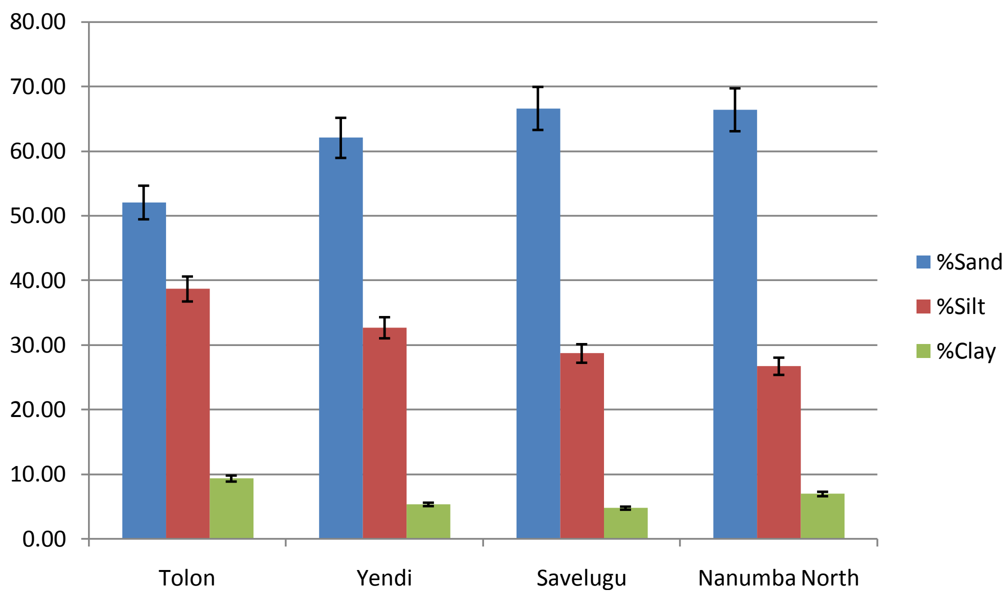

Figure 1. Percentage soil physical properties of four Districts of Northern Ghana.

Yendi Municipality to 0.24% at the Savelugu-Nantong district. The exchange potassium from the four districts had non-uniform measurement as shown in Table 4. The phosphorus content presented in Table 4 was significantly different ($P \leq 0.05$) across the four shea butter processing districts. The least recorded value of 2.49% was recorded at the Tolon and the highest of 4.31% at the Tolon district. Phosphorus and potassium were highest (4.31 and 0.24% respectively) at Savelugu and least (2.49 and 0.16%, respectively) at Tolon and Yendi respectively. The readily availability of potassium, phosphorus and nitrogen is not inconclusive. It is directly linked with the soil pH of 5.74 at Savelugu. At pH range of 5.5 to 7.5, there are sufficient microorganisms to breakdown the organic matter (Cooper, 1997); it is the best range for nutrient availability for plant uptake and so the second best yield of shea butter was at Savelugu. Phosphorus is involved in metabolic processes required for normal growth such as glycolysis and fatty acid synthesis and aids in seed formation. The phosphorus content in soils of northern Ghana is between 2.49 and 4.31% as shown in the composite Table 4.

The CEC content presented in Table 4 was significantly different ($P \leq 0.05$) across the four shea butter processing districts. The least recorded value of 6.25% was at the Yendi Municipality and the highest of 7.03% at the Tolon district. The CEC content was also statistically different ($p \leq 0.05$) with the Fishers least significant difference (LSD) analysis. The amount of shea butter in the shea nut kernel across the districts is affected by the cation exchange capacity (CEC). The least amount of butter (48.24%) was retrieved at Tolon which has the highest CEC of 7.03%. The Yendi Municipality recorded the highest butter (49.37%) content and the least CEC of 6.25%. Tolon had the highest clayey soil and the least sandy soil contents as shown in Figure 1. As a result the lowest organic carbon, organic matter and soil nitrogen are recorded in Tolon and hence the lowest butter content.

The specific gravity, which depicts the relative density

Table 5. Shea butter fats compared to soil chemical properties.

District	%Butter fats	%OC soil	%OM soil	%Total soil nitrogen	%Soil CEC	%Soil phosphorus	% Exchange potassium
Tolon	48.24	0.85	1.46	0.08	7.03	2.49	0.23
Yendi	49.37	1.18	2.04	0.10	6.25	2.89	0.16
Savelugu	48.78	1.08	1.86	0.10	6.31	4.31	0.24
N'ba North	48.38	1.01	1.75	0.10	6.83	2.94	0.17
P-value	0.001	0.001	0.001	0.001	0.002	0.001	0.001

of shea butter, according to this research is 0.91 across the shea producing centre. Many researchers (Hee, 2011; Munir et al, 2012; RTC, 2006) have reported this value for shea butter. Irrespective of the changing soil physical and chemical properties, the specific gravity remains the same. And thus soil chemical and physical properties have no effect on the specific gravity of shea butter.

The chemical properties of the shea butter (free fatty acids, acid value, pH, peroxide value, iodine value, ester value, Saponification value and Unsaponifiable value) do not have any direct relationship with the soil properties (Tables 3 to 5 and Figure 1). This observation suggests that irrespective of the varying soil properties the chemical composition of shea butter will remain the same. The free fatty acid content which falls within the range of 3.49% at Savelugu and 7.67% at Yendi with a mean value of 5.37% classifies the shea butter across the districts in the northern region under Group 3 according to the West African Regional Standards (RTC, 2006). The mean peroxide value of 8.06% as shown in Table 3 puts the shea butter from these districts under Group 1. This means that shea butter from Tolon, Yendi, Savelugu and the Nanumba North districts are classified as those suitable to be used in cosmetic and pharmaceutical industries and for direct consumption including uses in making soap and can further be refinement for direct consumption.

Conclusion

The most interesting findings of this research are that the shea nut tree is predominant in sandy soil areas where cation exchange capacity is low. Where there were high levels of sandy soils, there were equally low cation exchange capacity and this had direct positive impact on the fat (butter) content. Commercial plantations of shea trees will be best with sandy soil areas. Another discovery was that the organic matter, the organic carbon and the nitrogen contents were directly responsible for the quantity of shea butter in the shea kernels. The present research has also confirmed that soil properties have no impact on the shea butter chemical properties which has a huge responsibility in determining the quality of shea butter. The moisture content, the insoluble impurities, the peroxide value and the free fatty acid content of shea butter from this research confers quality on the shea butter produced from the Northern Regions of Ghana. The shea butter, according to this research, fall within the various grading systems of shea butter established by the Regional Technical Committee (2006) of the West African Regional Standards, and thus can be used in the pharmaceutical, confectionery, food and the cosmetic industries.

Conflict of Interest

The authors have not declared any conflict of interest.

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