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Colour analysis of syrup from malted and unmalted rice of different varieties

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ABSTRACT

The colour of rice syrup produced from flours of malted and unmalted rice of different varieties treated with a combination of starch hydrolyzing enzymes were analysed using CIE-LAB Spectrophotometric colorimeter after being filtered and/or centrifuged. The resulting syrups were processed as filtered unmalted hydrolyzed rice (FUHR), filtered malted hydrolyzed rice (FMHR), centrifuged unmalted hydrolyzed rice (CUHR) and centrifuged malted hydrolyzed rice (CMHR). Results showed that L* ranged from 60.16 to 68.57, a* ranged from 10.49 to 11.13 and b* ranged from 55.34 to 64.56. The magnitude of the colour values was an indication of the intensity of the rice syrup colour. Hue angle (°H*) ranged from 79.08° to 80.36° indicating less yellow in the CIE-LAB colour space and brown colour spectrum in the visible region of opponent colour chart. Total colour difference (ΔE) of syrups ranged from 0.50 to 1.72 for $\Delta E_{unmalted}$ while ΔE_{malted} ranged from 0.49 to 1.76. However, the $\Delta E_{filtered}$ ranged from 5.89 to 11.19 while $\Delta E_{centrifuged}$ ranged from 5.54 to 9.47 indicating that filtration and centrifugation contributed to non-significant difference ($p>0.05$) in colour attributes (ΔE) of the rice syrup, whereas very distinct colour difference (ΔE) was observed between rice syrups from malted and unmalted samples.

Introduction

Rice syrup can be added to many food formulations including being used as an alternative to refined sugar in many processed foods. It is a sweetener that is rich in compounds categorized as sugars and other nutrients such as minerals and amino acids. Rice syrups are produced by the action of saccharifying enzymes on cooked rice starch, followed by filtration and concentration by evaporation until a desired consistency is obtained.

Rice syrup quality comprises characteristics such as chemical composition and physical properties. They are often considered by consumers and end-users when evaluating the quality of the syrup. Colour is one of the most important quality components of foods. Colour is a perceptual phenomenon that depends on the observer and the conditions in which the colour is observed (Pathare et al., 2013). It is a characteristic of light, which is measurable in terms of intensity and wavelength. The colour of the material becomes visible only when light from a luminous object or source illuminates or strikes the surface.

The colour of processed food products such as rice syrup is derived from the formation of coloured compounds such as melanoidin produced during heat treatment as a result of Maillard reaction (Delgado-Andrade et al., 2010). The main constituents responsible for imparting these colour qualities in syrups are the presence of reducing sugars, amino acids and heat. The analysis of colour is an important consideration when determining the efficacy of a variety of postharvest treatments. The colour of food is the first quality parameter evaluated by consumers, and it is critical to product acceptance. Food appearance is determined mostly by its colour and is usually the first sensation that the consumer perceives and uses as a tool to either accept or reject food (Leon et al., 2006). Ozdogan and Yilmaz (2008) determined the effect of cooking on the colour of tomato jam

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*Corresponding author E-mail: chigozie.ofoedu@futo.edu.ng products by using CIE-LAB system while Tourjee et al. (1998) measured the colour variability between fresh and processed Clingstone peach differing in carotenoid composition by using CIE-LAB system.

Sensory characteristics show the major influence on the consumer's choice and, considering quality attributes on purchasing, visual impression which is also an aesthetic quality in food becomes the most relevant one. In this context, colour is very important indicator of quality, resulting in derived perceptions of visual expectation. It has been shown for a number of foods that colour significantly affects the perception of flavour attributes or texture sensations (Yousefi et al., 2012). Therefore, the objective of this study is to determine the variability in the colour of rice syrup from malted and unmalted rice of different varieties using CIE-LAB colour system as well as to investigate the effect of filtration and centrifugation of rice syrup on its colour.

Materials and methods

Sample Procurement

Ten (10) different varieties of locally available rice in Nigeria were obtained from rice breeders and the rice varieties were a blend of improved varieties and indigenous/native rice. Four varieties of paddy rice (FARO 44, FARO 52, FARO 57 and FARO 61) were purchased from Biotechnology Research and Development Centre of Ebonyi State University (EBSU), Abakiliki, Nigeria. The other six varieties of rice (Brown rice, IWA 3, Nwangenya, R8, Dragon 12 and 306) were obtained from local seed growers and were identified by the Biotechnology Research and Development Centre of Ebonyi State University, Abakiliki, Nigeria. The exogenous enzymes used in this research (Fungal α-amylase, Bacterial α-amylase and Amyloglucosidase) were obtained from Novozyme company, Germany.

The processing of samples and experiments were carried out using the facilities available at the laboratory of Department of Food Science and Technology, Federal University of Technology, Owerri and at The International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. Reagents and other used chemicals were of analytical grade.

Sample Preparation

The rice paddies of different varieties were manually cleaned by sorting in order to remove extraneous materials and damaged seeds. The sorting was followed by winnowing to remove dust. The cleaned paddy rice was further milled, sieved and packaged to obtain the unmalted rice flour as shown in Fig. 1.

Malting of Rice

The rice varieties were malted by adoption of barley malting protocols according to Kunze (2005). Steeping of each sample was done at the temperature of 20-25 °C for a period of 36 hours. The steep cycle involved alternating 12 hours wet-steep with 45 minutes air-rest period. After steeping, the grains were couched (heaped) on jute bags previously sterilized with dry heat. Samples were germinated within a temperature range of 25-30 °C, and removed after the second day of germination. Kilning was performed in a hot air oven at temperatures between 60-70 °C for 2 hours. Rice malt was continuously turned to aerate and achieve uniform controlled heat. Kilned samples were manually de-rooted by rubbing off with hands and winnowed to remove the rootlets and dust. The flow diagram of the above process in shown in Fig. 2.

Production of Rice Syrup

The method of Osuji and Anih (2011) with slight modification was used for the production of sugar syrup. The malted/unmalted rice flour (200 g) from different varieties was dissolved in 800ml of water in a beaker that was previously brought to a pH 11.0 with $Ca(OH)_2$.

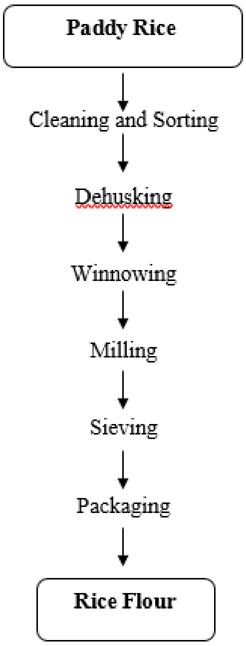

Fig 1. Flow diagram for the production of unmalted rice flour

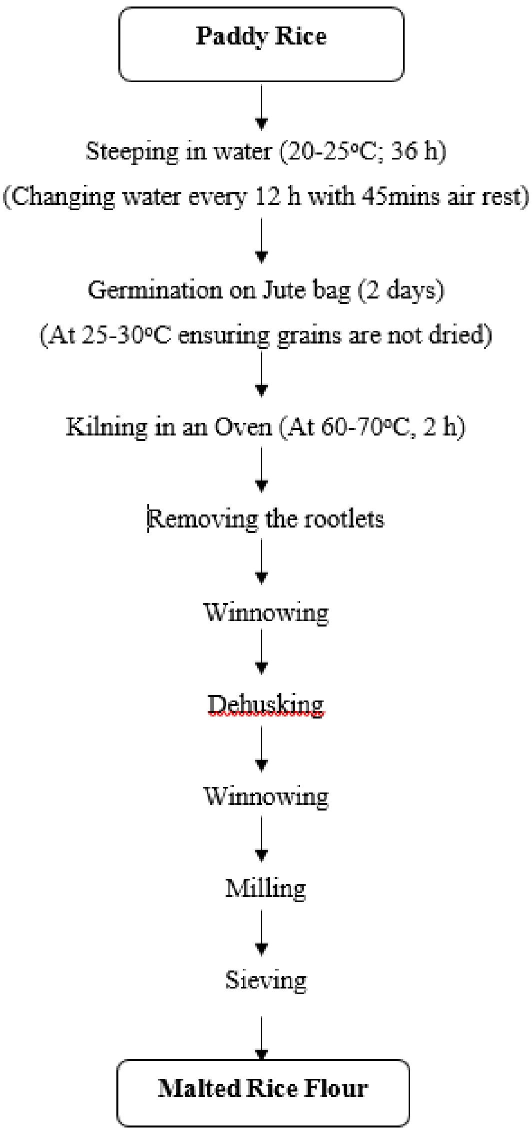

Fig 2. Flow diagram for the production of malted rice flour

The mixture was stirred continuously as the temperature was raised to 45 °C and 0.4 mL of Bacterial α-amylase and Amyloglucosidase (AMG) were added into the sample as the temperature was maintained for 20 min. With continuous but not vigorous stirring, the temperature of the sample mixture was raised to 55 °C and maintained at this temperature for 10 min. The conversion of starch in the medium was evaluated by pipetting 2 drops of iodine solution on about 1ml of the sample, poured out on the white ceramic tile. Another 0.4 mL of Bacterial α-amylase was added as the temperature of the content of the beaker was raised to 65 °C and maintained at this temperature for 1 hour. Furthermore, as the temperature of the sample mixture was raised to 90-93 °C, another (0.4 mL) of Bacterial α-amylase was added and the content of the beaker maintained at this temperature for 1 hour. The temperature of the sample mixture was cooled instantly to 60 ºC by placing it in an ice water bath and the pH was checked and controlled to 5.7-5.8 using a 1M HCl. Fungal α -amylase (0.4 mL) was added to the mixture thereafter as the temperature of the mixture was maintained at 60 °C for 1 hour. Throughout the enzymic digestion treatment the iodine test for starch was done periodically until the negative result was obtained which is an indication that all the starch has been hydrolyzed. After hydrolysis, the liquor was boiled for 10 min to denature enzymes. In one of the production processes, the converted slurry was filtered across a triple-layered muslin cloth while in the other process; the converted slurry was centrifuged at 1500 rpm for 15 min. The resultant filtrate, and supernatant respectively, evaporated as described by Shaw and Sheu (1992) to obtain the final syrup as shown in Fig. 3.

CIE Colour (L a* and b*) Analysis*

CIE L*a*b* (CIELAB) is a colour space specified by the International Commission on Illumination (French Commission Internationale de L'éclairage, hence its CIE initialism). It describes all the colours visible to the human eye and was created to serve as a device-independent model to be used as a reference. The CIE colour (L* a* and b*) values were measured using a Hunter Lab Scan Spectrophotometric colorimeter controlled by a computer that calculates colour ordinates from the reflectance spectrum as described by Adekunte et al. (2010) and Pathare et al. (2013). Reflection of samples in wavelength domains of 400 to 700 nanometers was measured. Then colour factors of samples were calculated by the aid of Equation (1), (2) and (3).

$$L^* = 116\,(Y/Y_n)^{1/3}-16 \qquad (1)$$

$$a^* = 500\,[(X/X_n)^{1/3}-(Y/Y_n)^{1/3}] \qquad (2)$$

$$b^* = 200\,[(Y/Y_n)^{1/3}-(Z/Z_n)^{1/3}] \qquad (3)$$

In the Equations (1), (2) and (3) amounts of X_n, Y_n, Z_n are the triple factors of standard lightness and the amount of X, Y, Z are triple factors of substance in CIE colour space. The colour factors of CIE-LAB colour space, that is, L*, a* and b* were calculated under lightness of D65 and visual angle of 10°. The syrup samples were placed on an optical glass tray, using the white plate of the colorimeter as the background. To calculate the amount of colour difference between the rice syrup samples, the following equation was used:

$$\Delta E^*_{ab} = (\Delta L^{*2} + \Delta b^{*2} + \Delta a^{*2})^{1/2} \qquad (4)$$

Moreover, for more precise evaluation of sample colour changes of different rice syrup samples, angle of hue (H^o) and colour purity (Chroma) (C^*) were calculated.

$$H^o = \text{Tan}^{-1}(b^*/a^*) \qquad (5)$$
$$C^* = (a^{*2} + b^{*2})^{½} \qquad (6)$$

In equations (1), (2) and (3), (L*) indicates the lightness of samples which is between 0 (ideal black) to 100 (ideal white), (a*) shows redness and greenness of samples and finally (b*) pictures yellowness and blueness of samples. Positive quantities for (a*) and (b*) report one redness and one yellowness respectively; but negative quantities report one greenness and one blueness.

There has been no definite limit for (ΔE_{ab}). A value for (ΔE_{ab}) proves the existence of colour difference and the bigger this amount the more increased the colour difference. The angle of hue (H^o) is measured in radian (0-360). If this factor (H^o) reveals 90, 180 and 270, the colours signified are red, yellow and green, respectively. The pure quantity in the least amount shows 0. When it rises, purity increases in such a way that more pure samples are expected to have livelier colours.

Statistical Analysis

Data obtained from this experiment was subjected to Analysis of Variance (ANOVA) in a 10 (**Rice Variety**) x 4 (**Treatments**) using SPSS 16 Software Package (2006). The treatments were; Filtered Unmalted Hydrolyzed Rice (**FUHR**), Filtered Malted Hydrolyzed Rice (**FMHR**), Centrifuged Unmalted Hydrolyzed Rice (**CUHR**) and Centrifuged Malted Hydrolyzed Rice (**CMHR**). All analysis were performed in duplicates. Results were expressed as Mean±Standard Deviation (SD). Significant differences between means were separated by the least significant differences (LSD) at p<0.05 between the sample parameters.

Results and discussion

The mean values of CIE-LAB colour (L*, a*, b*) of filtered and centrifuged unmalted and malted hydrolyzed rice of different varieties are shown in Table 1. There were significant differences ($p<0.05$) between the rice varieties as well as various treatments for all colour variables. The parameter a* takes positive values for reddish colours and negative values for the greenish ones, whereas b* takes positive values for yellowish colours and negative values for the bluish ones (Voss, 1999). L* is an approximate measurement of luminosity, which is the property according to which each colour can be considered as equivalent to a member of the grey scale, between black and white (Granato and Masson, 2010). The luminosity (L*) values of sugar syrups from unmalted samples were clearly higher than that of malted sample. Furthermore, the a* and b* values of sugar syrups from unmalted samples also indicated a clear pattern of being higher than sugar syrups from malted samples.

The magnitude of L*, a* and b* colour values was an indication of the intensity of the colour of rice syrups which therefore implies that syrups from unmalted samples were brighter, more reddish and yellowish than that from malted samples whereas syrups from malted samples appeared to be darker, less reddish and less yellowish than the unmalted samples. The decrease in L*, a* and b* colour values of malted samples as shown in Fig. 4 could be attributed to the formation of colour compounds (melanoidins) as the result of Maillard reaction during kilning and syrup production. Kunze (2005) reported that formation of individual colour compounds is very dependent on the concentrations of various components, the temperature and the water content during germination, pre-drying and kilning processes. Likewise, Kim and Lee (2009) reported the formation of melanoidins as a result of the Maillard reactions which occurred during the heating of syrups. However, the combined values of a* and b* for all the syrups was indicative of the dark brown colouration of the syrups and may have been due to the Maillard reaction during heat treatment as well as from caramelization (Whistler and BeMiller, 2008). In either case, brown coloured products are formed, giving the characteristic appearance of these syrups. The Maillard reaction takes place where reducing sugars and amino acids, proteins and/or other nitrogen-containing compounds are heated together (Pathare et al., 2013). According to Ofoedu et al. (2019), malted rice samples hydrolyzed with fungal α-amylase tend to have higher protein content and higher reducing sugar concentration, especially maltose, which are some of the factors that affect the intensity of colour formation during the Maillard reaction (Kunze, 2005). This also corroborates the findings of Mottur (1989) which reported that high reducing sugar contents are required to maximize colour development during heat treatment. On the other hand, it was reported by several authors (Martins et al., 2001; Coca et al., 2004) that during the Maillard reaction, the molecular weight of coloured substances increased due to polymerization reactions.

The mean values of Hue (°H*) and Chroma (C*) of rice syrups from filtered and centrifuged unmalted and malted hydrolyzed rice of different varieties are presented in Table 2. The hue angle (H*) is the qualitative attribute of colour according to which colours have been traditionally defined as reddish, greenish, yellowish, etc. It objectively reveals the human perception of colour. This attribute is related to the differences in absorbance at different wavelengths

(Pathare et al., 2013). A hue angle of 0° or 360° represents red hue, whilst angles of 90°, 180° and 270° represent yellow, green and blue hues, respectively. Generally, the results showed that the syrups had a hue angle less than 90° which indicated less yellow in the CIE-LAB colour space and brown colour spectrum in the visible region of opponent colour chart. Syrups from malted rice had significantly lower hue angle compared to the unmalted rice as shown in Fig. 5. The dominance of the hue is determined by Chroma (Pathare et al., 2013).

Chroma, on the other hand, is the quantitative attribute of colourfulness used to determine the degree of difference of a hue in comparison. It also describes the vividness and dullness of a colour. The higher the chroma values, the higher is the colour intensity of samples perceived by humans (Pathare et al., 2013). The chroma (C*) values were also found to be relatively low (56.28-65.49), corresponding to the low hue (°H*) values being in the dark brown colour range of the spectrum. It could be observed from the result that rice syrup malted samples had a lower chroma when compared to syrups from unmalted samples as shown in Fig. 6. This could be the result of the formation of higher concentration of coloured compounds (melanoidins) in the malted samples due to the Maillard reaction. The chroma values implied that syrups from unmalted samples are more saturated or vivid than their corresponding malted samples.

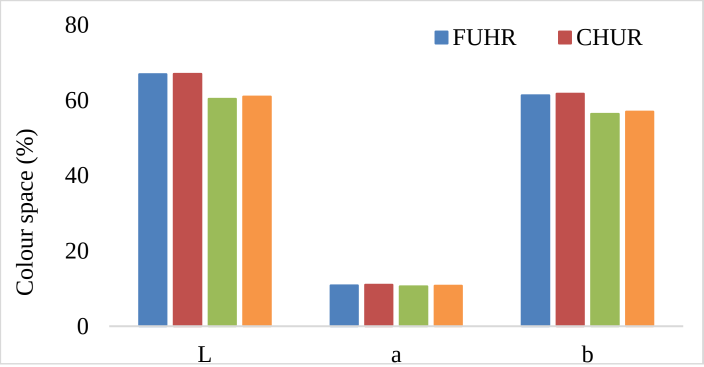

Fig 3. Average L*a*b* colour space of rice syrup

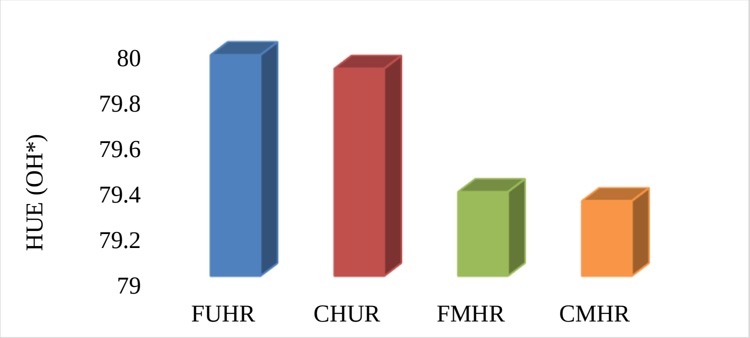

Fig 4. Average hue angle of rice syrup

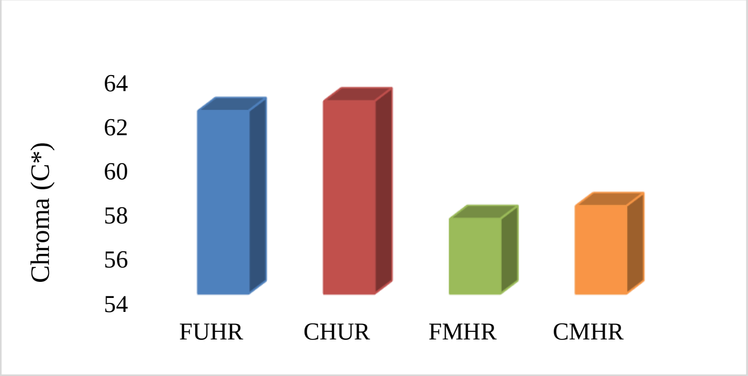

Fig 5. Average chroma value of rice syrup

Table 1. CIE L*a*b* Colour Analysis of Filtered and Centrifuged Rice Syrup

RICE VARIETY	L*				a*				b*			
	FUHR	**FMHR**	**CUHR**	**CMHR**	**FUHR**	**FMHR**	**CUHR**	**CMHR**	**FUHR**	**FMHR**	**CUHR**	**CMHR**
306 VARIETY	68.57^{a}±0.03	60.34^{e}±0.01	63.98^{h}±0.01	60.75^{f}±0.01	10.91^{b}±0.21	10.62^{c}±0.01	11.02^{c}±0.01	10.65^{fg}±0.01	64.16^{a}±0.01	56.59^{d}±0.01	64.56^{a}±0.01	56.86^{g}±0.03
BROWN RICE	66.66^{e}±0.01	60.46^{b}±0.01	68.06^{a}±0.01	61.54^{a}±0.01	10.85^{d}±0.01	10.59^{d}±0.01	10.98^{d}±0.01	10.69^{e}±0.01	56.05^{h}±0.00	55.58^{g}±0.01	57.06^{i}±0.01	56.97^{e}±0.01
DRAGON 12	65.59^{f}±0.01	60.29^{f}±0.01	65.89^{g}±0.01	60.48^{h}±0.01	10.67^{h}±0.01	10.49^{g}±0.01	10.76^{g}±0.01	10.64^{g}±0.01	59.65^{g}±0.01	56.63^{c}±0.01	60.05^{h}±0.01	57.13^{d}±0.01
FARO 44	65.56^{f}±0.01	60.36^{d}±0.01	66.36^{f}±0.01	61.36^{b}±0.01	10.88^{c}±0.01	10.71^{a}±0.02	11.06^{b}±0.01	10.97^{a}±0.01	60.35^{f}±0.01	57.59^{a}±0.01	60.65^{g}±0.01	58.26^{a}±0.01
FAR0 52	66.53^{e}±0.22	60.24^{g}±0.01	66.98^{e}±0.01	60.76^{f}±0.01	10.75^{f}±0.01	10.58^{d}±0.01	10.88^{f}±0.01	10.69^{e}±0.01	60.55^{e}±0.01	55.34^{h}±0.01	60.76^{f}±0.01	55.67^{g}±0.01
FARO 57	67.48^{c}±0.00	60.18^{h}±0.01	67.89^{b}±0.01	60.56^{g}±0.01	10.79^{e}±0.01	10.49^{g}±0.01	10.98^{d}±0.01	10.63^{g}±0.01	62.24^{c}±0.01	56.24^{f}±0.01	62.75^{c}±0.01	56.89^{f}±0.01
FARO 61	67.46^{c}±0.03	60.35^{d}±0.00	67.87^{cd}±0.01	60.80^{e}±0.01	10.90^{b}±0.01	10.53^{f}±0.01	11.06^{b}±0.01	10.77^{c}±0.01	63.35^{b}±0.01	57.45^{b}±0.01	63.89^{b}±0.01	57.59^{b}±0.01
IWA 3	66.57^{e}±0.03	60.43^{c}±0.01	66.88^{bc}±0.01	60.97^{e}±0.01	10.72^{g}±0.01	10.55^{e}±0.01	10.97^{d}±0.01	10.67^{ef}±0.01	62.25^{c}±0.01	56.68^{b}±0.01	62.76^{c}±0.01	56.97^{e}±0.01
NWANGBENYA	67.75^{b}±0.00	60.16^{i}±0.01	67.87^{cd}±0.01	61.13^{d}±0.01	10.99^{a}±0.01	10.67^{b}±0.01	11.13^{a}±0.01	10.86^{b}±0.01	63.35^{b}±0.01	56.56^{e}±0.01	62.56^{d}±0.03	57.44^{c}±0.01
R8	67.27^{d}±0.02	60.76^{a}±0.01	67.86^{d}±0.01	61.24^{c}±0.01	10.85^{d}±0.01	10.67^{b}±0.01	10.91^{e}±0.01	10.74^{d}±0.01	61.15^{d}±0.01	55.26^{i}±0.01	62.34^{e}±0.01	55.67^{s}±0.01
LSD	**0.16**	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.03**

Values are the means of duplicate determinations; a,b….means with the same superscript along a column is not significantly different (P>0.05). **Keys:** FUHR=Filtered Unmalted Hydrolyzed Rice; FMHR=Filtered Malted Hydrolyzed Rice; CUHR=Centrifuged Unmalted Hydrolyzed Rice; CMHR=Centrifuged Malted Hydrolyzed Rice

Table 2. CIE Hue (^{O}H*) and Chroma (C*) Values of Filtered and Centrifuged Rice Syrup

RICE VARIETY	°H*				C*			
	FUHR	**FMHR**	**CUHR**	**CMHR**	**FUHR**	**FMHR**	**CUHR**	**CMHR**
306 VARIETY	80.36±0.02	79.38±0.01	80.32±0.01	79.39±0.01	65.08±0.02	57.57±0.01	65.49±0.01	57.85±0.03
BROWN RICE	79.05±0.01	79.22±0.01	79.11±0.01	79.38±0.01	57.09±0.00	56.57±0.02	58.10±0.01	57.96±0.01
DRAGON 12	79.86±0.01	79.51±0.01	79.85±0.01	79.45±0.01	60.60±0.01	57.59±0.01	61.00±0.01	58.11±0.01
FARO 44	79.78±0.01	79.47±0.02	79.67±0.01	79.34±0.01	61.32±0.01	58.57±0.03	61.65±0.01	59.28±0.01
FAR0 52	79.94±0.01	79.18±0.01	79.85±0.01	79.13±0.01	61.49±0.01	56.34±0.01	61.72±0.01	56.81±0.01
FARO 57	80.17±0.01	79.44±0.00	80.08±0.01	79.42±0.01	63.16±0.01	57.21±0.02	63.70±0.01	57.87±0.01
FARO 61	80.24±0.01	79.61±0.01	80.18±0.01	79.41±0.01	64.28±0.01	58.41±0.01	64.84±0.01	58.58±0.01
IWA 3	80.23±0.01	79.46±0.01	80.09±0.01	79.40±0.01	63.16±0.01	57.65±0.01	63.71±0.01	57.96±0.01
NWANGBENYA	80.16±0.01	79.32±0.01	79.91±0.01	79.29±0.01	64.29±0.01	57.56±0.02	63.54±0.01	58.45±0.01
R8	79.94±0.01	79.08±0.01	80.08±0.01	79.08±0.01	62.10±0.01	56.28±0.01	63.29±0.01	56.69±0.01

Values are the means of duplicate determinations. **Keys:** FUHR=Filtered Unmalted Hydrolyzed Rice; FMHR=Filtered Malted Hydrolyzed Rice
CUHR=Centrifuged Unmalted Hydrolyzed Rice; CMHR=Centrifuged Malted Hydrolyzed Rice

Table 3. Total Colour Difference between Filtered and Centrifuged Rice Syrup

RICE VARIETY	UNMALTED				MALTED			
	ΔL*	Δa*	Δb*	ΔE	ΔL*	Δa*	Δb*	ΔE
306 VARIETY	7.60	-0.11	-0.40	7.61	-0.41	-0.035	-0.27	0.49
BROWN RICE	-1.40	-0.13	-1.01	1.72	-1.08	-0.100	-1.39	1.76
DRAGON 12	-0.30	-0.09	-0.40	0.50	-0.19	-0.150	-0.50	0.56
FARO 44	-0.80	-0.18	-0.31	0.87	-1.00	-0.260	-0.67	1.23
FAR0 52	-0.45	-0.13	-0.21	0.51	-0.52	-0.110	-0.33	0.62
FARO 57	-0.40	-0.19	-0.52	0.68	-0.38	-0.145	-0.65	0.76
FARO 61	-0.41	-0.16	-0.54	0.70	-0.45	-0.245	-0.14	0.68
IWA 3	-0.31	-0.25	-0.51	0.64	-0.54	-0.120	-0.29	0.70
NWANGBENYA	-0.12	-0.15	0.78	0.81	-0.97	-0.195	-0.88	0.64
R8	-0.59	-0.06	-1.20	1.33	-0.48	-0.075	-0.41	0.81

Table 4. Total Colour Difference between Unmalted and Malted Rice Syrup

RICE VARIETY	FILTERED				CENTRIFUGED			
	ΔL*	Δa*	Δb*	ΔE	ΔL*	Δa*	Δb*	ΔE
306	8.23	0.29	7.56	11.19	0.23	0.37	7.70	7.71
BROWN RICE	6.20	0.26	0.48	6.22	6.52	0.29	0.10	6.52
DRAGON 12	5.30	0.18	3.03	6.11	5.41	0.12	2.90	6.15
FARO 44	5.20	0.17	2.76	5.89	5.00	0.09	2.40	5.54
FAR0 52	6.29	0.17	5.21	8.17	6.22	0.19	5.10	8.04
FARO 57	7.30	0.30	6.00	9.45	7.32	0.35	5.90	9.39
FARO 61	7.11	0.37	5.90	9.24	7.07	0.29	6.30	9.47
IWA 3	6.15	0.18	5.57	8.30	5.91	0.30	5.80	8.28
NWANGBENYA	7.59	0.32	6.79	10.19	6.75	0.27	5.10	8.48
R8	6.51	0.19	5.89	8.78	6.65	0.17	6.70	9.40

The mean values of the total colour difference (ΔE) of filtered and centrifuged syrups and syrups from unmalted and malted hydrolyzed rice of different varieties are shown in Table 3 and Table 4, respectively. Table 3 describes the total colour difference of syrups between filtered malted hydrolyzed rice (FMHR) and centrifuged malted hydrolyzed rice (CMHR), and the total colour difference of rice syrups between filtered unmalted hydrolyzed rice (FUHR) and centrifuged unmalted hydrolyzed rice (CUHR). On the other hand, Table 4 describes the total colour difference of rice syrups between filtered unmalted hydrolyzed rice (FUHR) and filtered malted hydrolyzed rice (FMHR), and the total colour difference of rice syrups between centrifuged unmalted hydrolyzed rice (CUHR) and centrifuged malted hydrolyzed rice (CMHR). The parameter ΔL* takes positive values for lighter and negative values for darker, Δa* takes positive values for redder and negative values for greener, whereas Δb* takes positive values for yellower and negative values for bluer. From the results presented in Table 3, it was observed that the ΔL* value of all rice varieties and treatments was negative except for 306 (Unmalted) and this implies that rice syrups from filtered samples appeared darker than syrups from centrifuged samples. This could be the result of some insoluble materials in the syrup that passed through the filter medium, which affected and diffracted the wavelength of absorption of the syrup, unlike the centrifuged syrup samples. Centrifugation removed most of the insoluble materials in the syrup. Furthermore, the result showed that Δa* and Δb* had negative values for both unmalted and malted samples (Table 3), and this implies that syrups from filtered samples were greener and bluer than syrups from centrifuged samples.

From the results presented in Table 4, it was observed that the ΔL* value of all the rice varieties and treatments was positive and this implied that rice syrups from unmalted samples appeared to be lighter than syrups from malted samples. Moreover, the total colour difference (ΔE) is a measure of the magnitude of difference between two colours. Total colour difference in this study indicated the magnitude of colour difference between centrifuged samples and filtered samples and/or colour difference between unmalted samples and malted samples. A value for (ΔE) proves the existence of colour difference and the bigger this amount,he more increased the colour difference. The $\Delta E_{unmalted}$ ranged from 0.50 to 1.72 except for 306 variety while ΔE_{malted} ranged from 0.49 to 1.76 amongst the rice varieties. However, the $\Delta E_{filtered}$ ranged from 5.89 to 11.19 while $\Delta E_{centrifuged}$ ranged from 5.54 to 9.47.

According to Adekunte *et al*., (2010), differences in perceivable colour can be analytically classified as very distinct ($\Delta E>3$), distinct ($1.5<\Delta E<3$) and small difference ($\Delta E<1.5$). From the results obtained, it was observed that the total colour difference (FUHR-CUHR) of $\Delta E_{unmalted}$ and total colour difference (FMHR-CMHR) of ΔE_{malted} can be classified as small difference for all varieties while the total colour difference (FUHR-FMHR) of $\Delta E_{filtered}$ and total colour difference (CUHR-CMHR) of $\Delta E_{centrifuged}$ can be classified as very distinct. The total colour difference computation showed that there was a very distinct difference in colour between the rice syrups from malted samples and that from unmalted samples. The very distinct difference could be due to the variations in the concentration of melanoidin produced during heat treatment as a result of Maillard reaction. Furthermore, the computation also showed that utilizing either filtration or centrifugation contributed a small difference or no difference in the colour of their respective syrups for all the rice varieties. According to Patras et al. (2011), total colour difference was considered as the most sensitive parameter for the measurement of colour degradation in strawberry jam in response to temperature treatment.

Conclusion

The colour parameters of the syrups from different varieties of rice were affected by variety and malting treatment. The filtration and centrifugation did not affect the colour of the syrup. Improved colour measurement of syrups from rice grains can be achieved with the CIE-LAB system and could possibly be applied when predicting the product's colour.

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