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Research Article

Evaluation of main factors that affect frying efficiency during gari production using a mechanical stirrer technique

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Abstract: Frying is a unit process operation during *gari* production and is mostly performed by using mechanical-assisted stirrer technique (MAST). The factors' affecting the frying effciency of MAST is not clear. The current study focuses on the evaluation of main factors affecting frying effciency during *gari* production using MAST. The MAST consists of a pan of dimension support 560 by 120 mm, rotating shaft, bevel gear, pulley, belt, heating chamber, stirrer, bearing sand, and electric motor. The main factors considered were stirring speeds (30, 45, 60 rpm), and heating time (10, 15, 20 minutes), following traditional method, and used as control. The performance evaluation investigated on the machine includes effciency, loss and sensory properties of *gari*, using standard methods. The results showed that the MAST produces good sensory qualities of *gari*, promotes higher effciency (94.50%) and lower loss (4.13%) at stirring rate and heating time of 45 rpm and 20 minutes respectively. Whereas, the samples stirred using traditional method have effciency and loss of 85.23% and 8.69%, respectively. It is hoped that the information on the factors affecting the frying effciency during *gari* production using MAST is useful for the food industry.

Keywords: Gari Production, Stirring Speeds, Heating Time, Effciency, Food Industry

1. INTRODUCTION

Mechanical stirring technique is mostly used during *gari* production due to its high production rate, safety and convenience. *Gari* is produced by sieving wet cake into finely pieces (known as grits) and then roasting or frying the grits in a hot pan to form a dry and crispy product (Adekunle *et al.,* 2022; Akinnuli *et al.,* 2015; Bechoff *et al.,* 2019; Esheya, 2022; Olayanju *et al.,* 2018). During the frying process, the production of *gari* is generally determined by stirring techniques visa: manual (traditional) and mechanical technique. Traditionally, manual stirring technique is labour intensive, and time consuming, resulting into musculoskeletal disorders or discomfort of the operator, production of semi-dried cassava mass with high quality loss upon cooling (Samuel *et al.,* 2016; Babatunde & Taiwo 2018; Moses & Mohammed 2022). In order to overcome the above setbacks, the concept of mechanical-assisted stirrer technique (MAST) has been applied (Osueke *et al.*, 2012; Olayanju *et al.,* 2018). The technique involves the use of a stirrer that is attached to a rotating shaft in order to achieve a uniform heating on the pan. In this innovative technology, a shaft and spikes are arranged in the pan that prevents clumping and keep the material evenly spread to enhance efficiency, and produce dried *gari* with little or no quality loss (Oyeleke *et al.*, 2017). Several studies have shown that the application of MAST helps to enhance efficiency and improve the quality of dried *gari* in terms of appearance, color, flavor when compared with the ones dried by using manual stirrer (Sobowale *et al.,* 2014; Olayanju *et al.,* 2018; Adegbite *et al.,* 2019; Adinsi et al., 2019; Gbabo et al., 2020; Osunbade and Adejuyitan, 2020; Adekunle *et al.*, 2022). The applications of MAST depend on some factors such as sample mass, heating time, and stirring rates. Moreover, the available techniques for *gari* production, which utilizes MAST, have not been adequately optimized because of unavailable information on the factors that affects their efficiency

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(Adegbite et al., 2019; Gbabo et al., 2020; Adekunle et al., 2022). Thus, the objective of this study was to evaluate the main factors such as stirring speeds and heating time that affect frying efficiency during gari production using a MAST.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this research includes mechanical assisted stirrer technique, variable speed drives (VSDs), bearing, weighing balance, heating chamber, and cassava mass.

2.2 Machine Description and Working Principle

The machine consists of main components such as: pan, rotating shaft, bevel gear, frying chamber, and thermocouple, variable speed drives (VSDs), stirrer, belt and pulley, and machine frame. The pan of diameter 560 mm, height 120 mm and volume of 0.051 m3 was designed and constructed according to –Oyeleke et al. (2017). The machine frame supports the shaft and other parts of the machine. The machine operation is based on rotational motion with the use of bevel gear which serves dual purposes viz: (1) it reduces speed transmitted to the pinion shaft of the stirrer, and (2) converts horizontal motion to vertical motion (through an angle of 90o). Thermodynamically, the machine basically works on the principles of conductive heat transfer and motion transmission from the prime mover (electric motor). Heat generated by the charcoal is transferred to the dewatered cassava mash through the metallic "frying chamber" holding the mash for roasting to take place. The electric motor generates motion and passes it to the reduction gear arrangement, and the motion is used to evenly spread the cassava mash in the frying chamber in order ensure even distribution of heat and prevention of formation of bigger lumps. Figure 1 shows the picture of the machine.

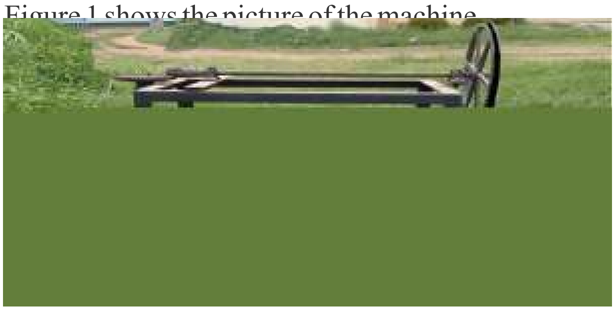

Figure 1: Pictorial View of the Machine

2.3 Experimental Procedure

During the experiments, a 3kg cassava mass was spread in the frying pan operated at stirring speed of 30, 45, and 60 rpm, heating time 10, 15, and 20 minutes and heating temperature of 110°C. The weight gradient of the samples was measured at 5 minute intervals, using a weighing balance, until it dropped to 0.09 ± 1 kg. At the end of the frying process, the samples were removed from the pan and cooled at ambient temperature for 2h. The cooled *gari* was packed and evaluated based on frying efficiency, frying loss, and sensory properties. The frying efficiency and frying loss was calculated according to Adegbite et al.(2019) with slight modification, as given in the equations (1) and (2) below.

$$\textbf{Frying efficiency} = \frac{W_{af}}{W_{bf}} \times 100 \quad (1)$$

$$\textbf{Frying loss} = \frac{W_{bf} - W_{af}}{W_{bf}} \times 100 \quad (2)$$

Where:

W_{bf} = weight of processed gari before frying

W_{af} = weight of processed gari after frying

2.4 Experimental Layout

The experimental layout is shown in Table 1 below.
Table : Experimental layout
Independent variables Dependent variables A1 B1 Frying efficiency A2 B2 Frying loss A3 B3 Sensory properties Where: A1 = 30 rpm, A2 = 45 rpm, A3 = 60 rpm, and B1 = 10 minutes, 15 minutes, and 20 minutes.

2.5 Sensory Properties

Color, flavor, taste and overall acceptability of the final product were evaluated using a 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like) with panelists of 24 gari consumers, including male and female. As part of the training, the panelists cleansed their palates with distilled water before tasting the sample anytime during the test as prescribed by Ray (2021).

2.6 Statistical Analysis

Data of the frying efficiency, frying loss and sensory analysis were evaluated in triplicates and analyzed with SPSS 21 software (IBM SPSS Inc., Chicago, Illinois, USA). Sensory results were compared using Duncan multiple range (DMRT) test.

3. RESULTS AND DISCUSSION

3.1 Efciency

Table 2 shows that the machine efficiency was observed to be increasing as the heating time is increasing. But, when the speed of the machine is increased up till 60 rpm, the frying efciency decreased. A frying machine operated at a speed higher than 60 rpm has the potential to break the grits into finely particles, reduces weight, thus lowers the efficiency (Gbabo et al., 2020). As shown in Table 1, the frying efficiency of 94.50% was observed when the heating time and the speed of the machine were 20 minutes and 45 rpm, respectively. This result is in agreement with the observation of Sobowale et al. (2014), in which maximum functional efficiency of 92.20 % in a mechanical powered gari fryer. Moreso, the result supported the findings of Gbabo et al. (2020), that a machine operated at a high speed breaks the cassava mass, while low speed (45 rpm) machine does not break the cassava mass, leading to low material loss, and preserved texture.

Table 2: Duncan multiple range test (DMRT) of the effect of heating time and stirring speed on the frying efficiency of mechanical-assisted *gari* fryer

Treatment			Frying efficiency (%)	Frying loss (%)
Heating time (min)	Control		85.23 ± 0.2^{d}	8.69 ± 0.3^{a}
10	Stirring speed (rpm)	30	93.45 ± 0.2^{c}	5.33 ± 0.3^{b}
		45	93.50 ± 0.2^{c}	5.30 ± 0.3^{b}
		60	93.40 ± 0.2^{c}	5.05 ± 0.3^{b}
15	Stirring speed (rpm)	30	94.10 ± 0.2^{b}	5.26 ± 0.3^{b}
		45	94.20 ± 0.2^{a}	4.48 ± 0.3^{c}
		60	94.15 ± 0.2^{b}	5.15 ± 0.3^{b}
20	Stirring speed (rpm)	30	94.20 ± 0.2^{a}	4.88 ± 0.3^{c}
		45	94.50 ± 0.2^{a}	4.13 ± 0.3^{c}
		60	94.15 ± 0.2^{b}	4.30 ± 0.3^{c}

*Samples with the same superscript are not significantly diferent

3.2 Loss

Table 1 showed the average frying loss for the main processing factors. The frying loss was observed to reduce as the heating time and stirring speed were increasing. The minimum loss of 4.13% was observed when the machine was operated at a speed of 45 rpm, and heating time of 20 minutes. The reductions in loss could be attributed to the uniformity of the spread of the cassava mass, and the fast heat and mass transfer during the frying process (Oyeleke *et. al,* 2017). Fast heat and mass transfer are important phenomena that lead to desirable quality attribute in *gari* production. Uniform spread of cassava mass has been reported to be responsible for low frying loss, product stability and good sensory quality during *gari* production (Sobowale *et. al.,* 2014). Olayanju *et al.* (2018) reported that mechanical frying machine exhibits low frying loss, when compared with the conventional method, due to the presence of revolving spindle.

Table 1 revealed that the heating time and frying rate affected the loss of the final product. It can also be observed that the sample fried under traditional method has frying loss of 8.69%, suggesting that traditional method with loss up to 8.69% would produce coarse dried *gari* after 20 minutes.

3.3 Sensory Properties

The sensory (color, flavor, taste, and overall acceptability) properties of the final *gari* fried under all the process conditions increased with increase in the heating time and frying rate. The samples fried under traditional method showed lower sensory properties upon cooling, which reduced the overall acceptability. Typically, increase in color and taste were observed at all the process conditions, with values decreasing from 7.00 ± 0.4 to 6.50 ± 0.4, from 7.00 ± 0.02 to 6.50 ± 0.02, respectively, for the heating time of 15 minutes and stirring speed of 60 rpm. The slight decrease in the color after frying was due to the maillard reaction, resulting from the biodegradation of lactic acid bacteria during the pre-heating process. Osunbade and Adejuyitan (2020) reported that the off color of fried *gari* is largely depended on maillard reaction occurring during pre-heating stage. At pre-heating stage, lactic acid bacteria hydrolyse carbohydrates in the cassava mass into reducing sugar, alcohols and organic acids. The production of the organic acids, which increases with heating time, leads to an increase in acidity of the sample and the resultant decrease in color. Several studies have shown that sensory properties of *gari* and related foods are influenced by processing methods (Obadina et al., 2013; Adinsi et al., 2019). The taste is also found to decrease slightly as the heating time is increased up to 20 minutes as shown in Fig. 4.

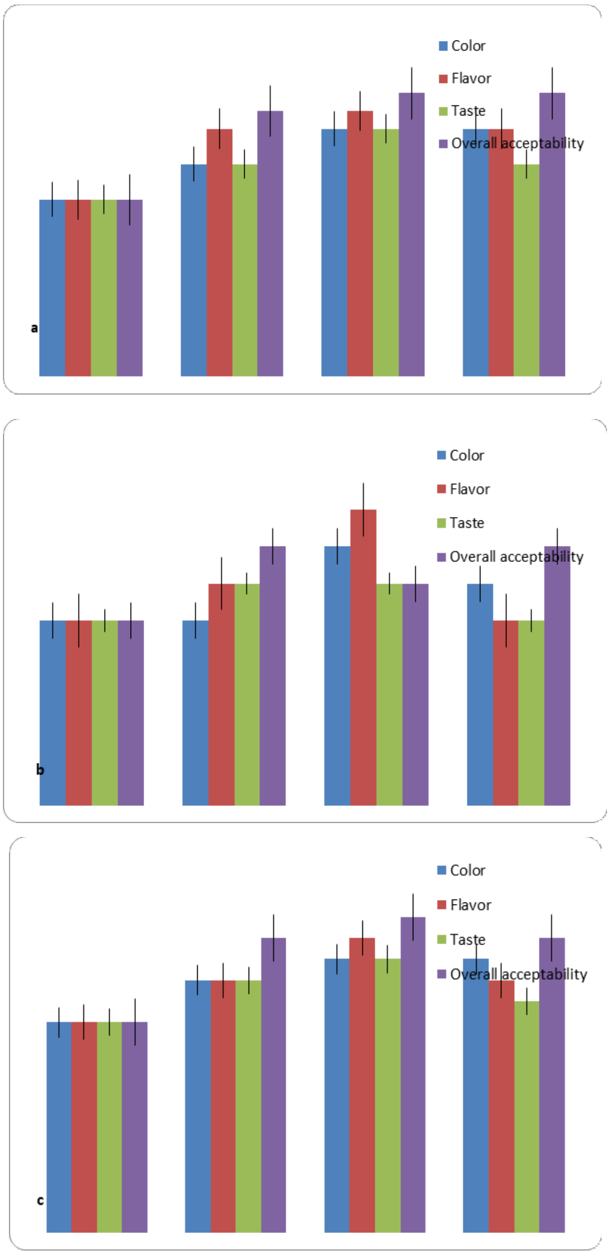

Figure 4: Effect of heating time on the sensory properties of dried gari at stirring speed of (a) 30 rpm (b) 45 rpm (c) 60 rpm (relative to the ones dried under traditional method).

Generally, all the sensory properties of the samples fried by MAST were much higher than the samples fried under conventional frying method. This is because along with the increase of heating time (10, 15, and 20 minutes) at 110oC, the moisture content of the cassava mass decreased slowly while the volatile compounds (nutrients) were well-preserved. Figure 4 revealed that a slight significant decrease in flavor occurred only after 20 minutes of heating and at 45 rpm stirring speed. At stirring speed of 45 rpm, and heating time of 15 minutes, no significant differences were noted in color, flavor, and taste of the sample, suggesting that MAST has great potential to produce good quality gari.

4. CONCLUSION

Main factor level affecting the quality of fried gari produced by using MAST is a major concern in the food industry. The current study evaluated the effect of factors such as stirring speed (30, 45 and 60 rpm) and heating time (10, 15 and 20 minutes) on the frying efficiency, frying loss and sensory properties of fried gari using MAST. The results of the study showed that MAST promotes higher frying efficiency of 94.50%, causes lower frying loss 4.13% and enhances good sensory properties of fried gari when the machine was operated at 45 rpm for 20 minutes, when compared with the samples fried by using traditional (manual) method. Further study on the effect of the interactions of the factors on the efficiency of MAST is recommended.

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