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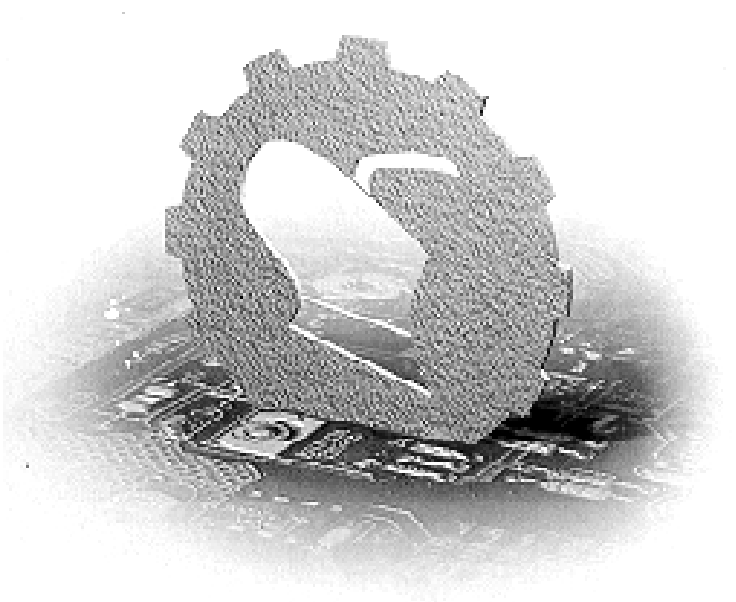

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UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
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EFFECT OF FREEZE DRYING ON QUALITIES OF FRESH COW MILK AND SOY CHEESES

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Abstract: The effect of freeze drying on the qualities of fresh cow milk and soy milk cheeses was investigated, with a view to preserve and present them in a more stable and portable form. The cow milk cheese and soy milk cheese used were freshly prepared with dimension of 2 x 3 cm and 0.2 cm thickness. The cow milk and soy cheese were divided into 6 portions of 100 g each. The initial properties of the cheeses samples been determined using a portion of 100 g each, the remaining 500 g were freeze dried. The nutritional, microbial and sensory qualities of the freeze dried cheeses were determined using standard methods. Results showed that freshly prepared cow milk cheese contains 54.02% moisture, 20.34% protein, 6.40% ash, 18.11% fat and 4.25% carbohydrate, 3.52mg/100g sodium, 7.02mg/100g potassium, 5.22mg/100g magnesium, 6.32mg/100g iron, 11.12mg/100g calcium, $3x10^3$cfu/g bacteria and 2.54 x 10^6cfu/g fungi whereas freshly prepared soy cheese contains 50.89% moisture, 22.05% protein, 6.31% Ash, 19.02% fat and 4.06% carbohydrate, 3.52mg/100g sodium, 7.04mg/100g potassium, 5.14mg/100g magnesium, 6.20mg/100g iron, 10.76mg/100g calcium, $2.76x10^3$cfu/g bacteria and 2.60 x 10^6cfu/g fungi. The moisture and fat contents of the freeze dried cow milk and soybean milk decreased significantly ($P < 0.05$) from 54.02% to 4.28%, 18.11% to 4.05% and 50.89% to 4.19%, 19.02% to 4.30% respectively. Freeze drying significantly decreased the bacteria and fungi contents of fresh cheeses; it decreased from $3x10^3$cfu/g to 2.72 x 10^3cfu/g, 2.54 x 10^6cfu/g to 2.35 x 10^6cfu/g, and 2.76 x 10^3cfu/g to 2.54 x 10^3cfu/g, 2.60 x 10^6cfu/g to 2.38 x 10^6cfu/g for cow milk and soy milk cheese respectively.

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The carbohydrate, protein, ash content, calcium, sodium, magnesium, taste, appearance, flavour, acceptability of the cow milk cheeses increased significantly ($P < 0.05$) when freeze dried. Decreases in moisture content, fat and microbial counts of cheeses would enhance its stability and shelf life if properly packaged.

Keywords*: Cheese, freeze drying, nutritional qualities, microbial qualities, sensory qualities.*

INTRODUCTION

Cheese is a product made from the curd obtained from milk by coagulating the casein with the help of rennet or similar enzymes in the presence of lactic acid microorganism [1]. Cheese is the fresh or ripened product obtained after coagulation and whey separation of milk, cream or partly skimmed milk, buttermilk or a mixture of these products, it can also be made from the milk of cows, sheep, goats and camels or mixture of two of these [2]. The objective of cheese making is to obtain the optimum cheese composition with respect to moisture, acidity, fat, protein and minerals. Cheese provides a high concentration of nutrients relative to its energy content. The nutritional composition of cheese depends on the type of milk used and the manufacturing and ripening procedures [3].

Each type of milk imparts the characteristics quality of cheese made from it and the resulting cheese will differ in its proprieties, body texture, and flavor [4]. There are great varieties of cheese, some are perishable and must be consumed within few days while other can be stored for years [2]. White cheese is the only type of cheese available to the public in large quantities in most Nigerian markets. Warsama *et al.* [5] reported that Nigerian white soft cheese contained 47.8% total solids, 14.0% fat, 15.9 % protein and 6.2% ash.
Natural cheese should be processed at acceptable temperatures to ensure good consistenc y, as a high temperature contributes to moisture evaporation and development of undesir able bacteria and other faults [1].

The macro and micro-nutrients contained within foods all show varying degrees of stability when foods are stored or processed. One of the greatest challenges facing food scientists/technologists in Nigeria today is the upgrading of the traditional technologies of cheese processing and preservation [6]. The traditional methods of cheese processing and preservation in Nigeria remain at the empirical level. The processes are laborious, time consuming and invariably the quality of the products require substantial improvements [7]. Handling and preservation of cheese is a problem which causes excess losses and a short shelf life on account of its high moisture content, which is responsible for the rapid deterioration. Cheese processing and the various preservative methods have inevitable consequences on the nutritional value of cheese. The macro and micro nutrients contained within the cheese all show varying degrees of stability when cheese are processed and stored [2].

Biochemistry of fresh cow milk and soy cheeses shows quite similar compounds including proteins, lipids, carbohydrates, esters, alcohols, aldehydes and minerals [8].

The physiochemical changes caused by processing of soy cheese are quite similar to those of cow milk cheese, *e.g.* proteolysis, *i.e.* formation of amino acids from larger protein molecules, lipolysis, i.e. conversion of fats into smaller units called fatty acids, and production of aldehydes, alcohols, esters, etc. [9]. The processing steps like coagulation, pressing, cutting, salting, ripening, etc. are almost similar, with some exceptions due to the use of different kind of cultures [10].

The main difference between animal milk and soy milk is that soy milk does not contain lactose and casein, but this does not affect cheese making because soy sugars can serve the role of lactose, while soy milk proteins have the same role like milk proteins [11]. Owing to the worldwide shortage of food, attempts have been made to find alternative sources of protein, particularly for the nations where malnutrition exists. Soybeans particularly are plentiful, relatively inexpensive and rich in protein. Soy-based foods may provide additional benefits for the consumer due to their hypolipidemic, anti-cholesterolemic, anti-atherogenic properties and reduced allergenicity. It provides an alternative source of protein for people who are allergic to milk protein [2], [8].

Soy cheese and cow milk cheese get spoilt or rancid after some days; therefore there is a need to extend the shelf life by destroying or inhibiting micro-organisms and slowing down enzymes. One of the ways by which cheese can be preserved is by freeze drying method, and this method can transform the cheeses into forms that have longer shelf life rather than keeping them in fresh forms which are perishable [12]. Because of the absence of liquid water and the low temperature (approx. 20°C) used during freeze drying operation, most of deterioration and microbiological reaction are stopped [13]. Due to lack of liquid water and the low temperature (approx. 20 °C) used during the freeze drying process, the bulk of degradation and microbiological reaction was halted [13]. For freeze dried products shrinkages are removed, minimal degradation of flavour, aroma, vitamins, and near-perfect preservation outcomes are produced. The objective of this work is to determine the effect of freeze drying on the qualities of fresh cow milk and soy milk cheeses.

MATERIAL AND METHODS

One thousand five hundred grams (1500g) of soy beans and three litres (3l) of fresh cow milk was purchased at Kure Market Minna Niger State. Soy cheese and cow milk cheese used for this study was produced in the Crop Processing and Storage Laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State, Nigeria.

Reagents and Instruments

The following reagents were used during freeze drying, packaging and analysis of both cheeses.

Reagents

Distilled water, petroleum ether, boric acid, hydrochloric acid, mixed indicator, n-hexane, nitric acid, potassium hydroxide, polyethylene bag.

Instrument and Apparatus

The instrument used for this research study are drying racks, sealing machine, lyophilizer, petri-dishes, desiccators, filter paper, electronic weighing balance, soxhlet apparatus, digestion block, pipette, conical flask, beakers, muffle furnace, flame photometer, atomic absorption, spectrophotometer, funnel, thistle funnel, measuring cylinder, kjeldahl apparatus, metallic tray.

Methodology

Fresh whole milk was used as prescribed by Amano [14] in the production of cow milk cheese. The fat content of the milk was reduced by keeping the milk settled for about one hour then the top layer was skimmed off (high fat milk or cream). The milk was heated to about 85°C to destroy most of the bacteria present and also to increase yield through precipitation of the whey proteins [15], Lemon juice (Coagulant) was diluted with an equal quantity of clean fresh water so that the lemon juice can be distributed uniformly. About 30 ml of lemon juice per litre of milk was added and stirred while carefully adding the lemon juice [9].

The curd precipitated almost immediately. Stirring continued for about three minutes after adding the lemon juice and then the curd was allowed to settle for 15 minutes. The curd was separated from the whey by draining through a muslin (cheese) cloth. While draining the whey, the curd was stirred to prevent excess matting [15]. Salt was added to the curd at a rate of about 4 g for every 100 g of curd and mixed properly. The quantity of salt may be varied to cater for the consumers taste preferences. The curd was transferred to a mould (container) lined with muslin (cheese) cloth. The curd was wrapped with the muslin (cheese) cloth and a wooden follower was fitted neatly inside the mould to enable the curd to be pressed [7]. The curd was pressed by placing metal weights on top of the wooden follower. The cheese was removed from the mould and then cut into sizes of 2x3cm dimension and thickness of 0.2cm. It was taken to the laboratory and freeze dried. The freeze dried samples were then packaged in the different packaging materials for further analysis.

The production of the soy cheese from soy beans was carried out as prescribed by Connor [16], 2003. About 1500g of properly cleaned soy beans was soaked in water for 12-14 hours after which the soybeans was dehulled, grinded and mixed with water. A sieve was used to separate the milk from the chaff in the mixture [9]. The milk was boiled (pasteurizes) and allowed to cool while the coagulant (Lemon juice) was added to the milk to form curd. The curd was wrapped with the muslin (cheese) cloth and pressed in a mould to remove the water present in the curd [17]. The hardened cheese was then cut into sizes of 2x3cm dimension and thickness of 0.2cm. The soy cheese was then taken to the laboratory and freeze dried. The freeze dried samples were then taken for further analysis.

Nutritional Analysis

The nutritional composition of samples A (cow milk cheese) and B (soy milk cheese) was determined according to the method described by the Association of Official Analytical Chemists [18]. The procedures for the determination of the nutritional properties of cow milk and soy cheese are as follows:

Determination of moisture content

The petri-dish was washed thoroughly and dried in an oven for few seconds and removed, cooled to room temperature in the desiccators. The petri-dishes were weighed using the electric weighing balance and their corresponding weight was recorded as W_1, Five grammes (5g) of sample was measured and added to the petri-dishes, the weight of the petri-dish and the sample was recorded as W_2.The petri-dishes (containing their respective samples) was dried in an oven at 105^0C until constant weight [18]. After the drying time elapsed, the samples was removed from the oven and cooled in the desiccators to room temperature, while they are reweighted one after another and the new weight (Weight of petri-dishes +dried sample) was recorded as W_3. The moisture content or percentage moisture (dry basis) for each sample was then calculated as:

$$\text{Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} * 100 \quad (1)$$

Where:

W_1= Weight of petri-dish, g.

W_2= Weight of petri-dish and initial sample, g.

W_3= Weight of petri-dish and dried sample, g.

Determination of Ash content

Three porcelain cubicles are thoroughly washed, heated, cooled in desiccators and weighed using the electronic weighing balance and the cubicles weight were recorded as W_1. Two grams (2g) of each sample were added to its corresponding crucibles, the new weight of crucible and the samples was recorded as W_2. After this, the samples were heated in a muffle furnace at 550°C for two hours to ash. At the end of the ashing period the samples was light grey in colour [19]. Removing the sample with the aid of tongs, the samples was cool in desiccator for some minutes prior to weighing. After cooling, the samples was weighed and the weight was recorded as W_3. The percentage ash for each sample was then calculated as:

$$\% \text{ Ash (dry basis)} = \frac{\text{weight of Ash}}{\text{weight of original cheese}} \text{ x } 100\% \quad (2a)$$

$$\% \text{ Ash} = \frac{W3 - W1}{W2 - W1} \text{ x } 100\% \quad (2b)$$

Determination of fat content

The fat content was determined by the procedure of [18]. Three 250ml beakers was thoroughly washed, heated and cooled in desiccators. Three filter papers were selected and their corresponding weights was recorded as W_1. Two grams (2g) of each sample was measured into each of its corresponding filter paper and the new weight recorded as W_2 approximately. The filter paper with their respective sample in them was then neatly folded and closed in a manner that the sample was perfectly locked in them. Each of the dried beakers was filled with about 300ml of petroleum ether boiling point 40-60°C.

The Soxhlet apparatus was then assembled, each filter was placed in each extraction chamber of the entire Soxhlet set up, and the top controlling the continuous flows of water into the condenser was open.

The power was on and the heating temperature was regulated to 50°C until the petroleum ether in the boiling flask started to boil, then the heating temperature was regulated down to 30°C. The apparatus was allowed to reflux for 6hours, at the end of the stipulated time (6 hours). The filter paper was removed carefully and taken to be dried in an oven for an hour at 105°C after which it was then cooled in a desiccator for some minutes, the new weights of the filter paper along with their contents are then measured again using the electric weighing balance and the weights measured was recorded as W_3. Finally, the percentage of fat was then calculated using the formula:

$$\% \text{ of Fat} = \frac{\textbf{weight of Fat } (W3-W1)}{\textbf{original Sample } (W2-W1)} \text{ x } 100 \quad (3)$$

Determination of crude protein content

About 0.5g of each sample was weighed into three kjeldahl flask; 20cm^3 conical flask, H_2SO_4, and 0.98g of selenium tablet was added to each sample in its tube to act as a catalyst. The mixture was then heated at a low temperature for about 15 minutes and then increased to a higher temperature for 30minutes and then at extra-high temperature until the sample was digested; at this stage, the solution was clear and colourless. The samples are then allowed to cool for a while. This was followed by the distillation of each sample using a kjeldahl distillation setup. 5mm of 2% Boric acid was prepared and poured into a 100ml conical flask (as a receiving flask), 3 drops of mix indicator (bromocresol green and methyl) was added to the receiving flasks.

The receiving flask was then placed under a condenser such that the tip of the condenser tube was below the surface of the boric acid. 5ml of the digested sample was then pipette into the body of the body of the apparatus via the small funnel aperture and washed down with distilled water followed by 5ml of 60% NaOH solution. Steam was passed continuously through the set up for 7 minutes to collect enough ammonium sulphate after which the receiving was removed and the tip of the condenser washed down into the flask. The condenser water was also removed, the distillate or solution in the receiving flask was then titrated using 0.05m hydrochloric acid and the titer value was recorded as T_1. The percentage Nitrogen was then calculated as:

$$\% \text{ of Nitrogen} = \frac{\textbf{T X M X 0.014 X V}}{\textbf{W}} \text{ X } 100\% \quad (4)$$

Molarity of acid = M
Where V = 10
Control Titre = T
% of crude protein = % of Nitrogen x conversion factor Protein conversion factor = 6.23

Carbohydrate

% of carbohydrate = 100% - (% of fat + % of crude protein + % of Ash + % of crude fibre).

Determination of potassium concentration

About 0.5g of the sample was first digested with 500ml of acid mixture (650ml conc., HNO_2, 80ml per chloric acid; 20ml conc. H_2SO_4) and the sample was then heated until clear digestions was obtained and allowed to cool down. The digested sample was then diluted with 500ml distilled water, a stock solution containing 100mg/ml of K^+ ions are prepared to dissolve 1.907g of KCl in water. The potassium emissions measured in air acetylene flame. A calibration curve of potassium emission against concentration was drawn and reading was noted and recorded.

Determination of magnesium concentration

Five *ml (5ml)* aliquot of the sample solution was measured into a 100ml conical flask. 5ml ammonium chloride-ammonium hydroxide buffer solution was then added followed by 1ml of triethanolamine. Three drops of *10%* KCN solution and few drops of EBT indicator solution was then added. The content in the flask was then thoroughly mixed by shaking and then titrated with 0.02 NEDTA solutions from a red to blue end point. Magnesium concentrations were then calculated.

Determination of iron concentration

Aliquots of standard sample and blank pipette into tubes and absorbance measured at 248nm using air-acetylene flame. Calibration curve of absorbance was then drawn against the concentration of iron to determine the iron concentration.

Sensory Evaluation of Freeze dried Cow milk and Soy Cheese

Ten panelists who are familiar with the cow milk cheese and soy cheese were used for the sensory evaluation. Evaluations are made on a nine point hedonic scale with 9 indicating like extremely, 6 indicating like, 3 indicating dislike and 1 indicating dislike extremely. The fresh and freeze dried samples of cow milk and soy cheese were checked for colour, flavour, texture and overall acceptability.

Microbial Qualities Determination

The microbial qualities of the fresh and freeze dried samples of cow milk and soy cheese were determined using standard methods as prescribed by Compendium of Methods for the Microbiological Examination of Foods [20] and Bacteriological Analytical Manual [21].

Determination of bacterial count in Cheese

For each dilution to be plated, aseptically 1ml sample suspension was transferred to 3 plates of Baird-parker agar, distributing 1ml of inoculum equitably to 3 plates. Inoculum was spread over the surface of the agar plate using sterile bent glass streaking rod. The plates are kept in upright position until inoculum was absorbed by agar (about 10minutes) on properly dried plates.

The plates were inverted and incubated for 45hours at 35^oC. Plates containing 20-200 colonies were selected.

Colonies with typical appearance of bacterial are circular, smooth, convex, moist, 2-3mm in diameter on uncrowded plates, gray (jet black) frequently with light coloured (off white) margin. Colonies have gummy consistency when touched with inoculating needle.

Determination of fungi count in cheese

The sample dilution containing fungi was placed in a kjeldahl flask. An alcoholic solution was used as indicator. Sufficient water was added to bring the total volume to 100cc. The flask was connected to the condenser and the suction started. The mixture was brought to boiling, then the MNO_2 was added but only after the vapours are condensing in the reflux condenser. The oxidizing agent was added drop by drop at a rate of not more than 1 per second until an excess has accumulated in the flask. When colloidal MNO_2 was used, an actual excess was present for at least 10minutes. The addition of the oxidizing agent was up to 10 minutes. This excess in turn was removed by one drop of 0.1N of thiosulphate solution. The end point was finally adjusted with the dilute iodine solution in such a manner that one drop of this dilute iodine solution produces a clearly discernable change, but not a deep blue in the colorless solution.

Statistical Analysis

All experiments were carried out in three replicate. Data obtained was analyzed statistically using SPSS 20.0 statistical package to determine the analysis of variance (ANOVA) and the Duncan multiple range test to separate the means. Time series regression analysis was used to develop a model to predict the effect of packaging materials and storage duration on selected nutritional, microbial and sensory qualities.

The freshly produced sliced soy and cow milk cheese used for the experiment are as shown in plate I and II while the freeze dried soy and cow milk cheese are shown in plate III and IV.

Plate I. fresh sliced soy cheese

Plate II. Fresh sliced cow milk cheese

Plate III. Samples of freeze dried soy cheese

Plate IV. Samples of freeze dried cow milk Cheese.

RESULTS AND DISCUSSION

The Nutritional, Microbial and Sensory Qualities of Fresh Cow Milk and Soy Milk Cheeses

The results of the nutritional, microbial and sensory qualities of fresh cow milk and soy cheese are as presented in Table 1.

Table 1. Nutritional, microbial and sensory qualities of fresh cow milk and soy milk cheeses.

Qualities	***Fresh Cow Milk Cheese***	***Fresh Soy Cheese***
Moisture Content (%)	*54.02±0.01*	*50.89±0.12*
Ash (%)	*6.40±0.32*	*6.31±0.31*
Protein (%)	*20.34±0.50*	*22.05±0.02*
Fat (%)	*18.11±0.06*	*19.02±0.58*
CHO (%)	*4.25±0.20*	*4.06±0.10*
K (Mg/100g)	*7.02±0.03*	*7.04±0.04*
Mg (Mg/100g)	*5.22±0.11*	*5.14±0.14*
Fe (Mg/100g)	*6.32±0.12*	*6.20±0.32*
Ca (Mg/100g)	*11.12±0.40*	*10.76±0.60*
Na (Mg/100g)	*3.30±0.60*	*3.52±0.85*
Bacterial (CFU/g)	$3.00x10^3$*±0.01*	$2.76x10^3$*±0.02*
Fungi (CFU/g)	$2.54x10^6$*±0.05*	$2.60x10^6$*±0.10*
Colour	*7.00±0.05*	*7.10±0.02*
Aroma	*6.50±0.01*	*5.40±0.01*
Taste	*6.50±0.70*	*7.00±0.05*
Appearance	*6.10±0.01*	*6.50±0.02*
Overall Acceptability	*7.00±0.05*	*7.20±0.01*

The results showed that fresh cow milk cheese and fresh soy cheese contain 54.02% and 50.89% moisture respectively, this is similar to previous report by [2], who obtained 53.10% moisture for cow milk cheese and 50.25% moisture for soy cheese.

The fresh cow milk cheese contains 6.40% ash, 20.34% protein and 18.11% fat while the fresh soy cheese contains 6.31% ash, 22.05% protein and 19.02% fat (Table 1).

The result of the mineral composition of the fresh cow milk cheese showed that the value for the sodium, potassium, magnesium, iron and calcium content are 3.30mg/100g, 7.0mg/100g, 5.22mg/100g, 6.38mg/100g and 11.12mg/100g respectively. Sodium, potassium, magnesium, iron and calcium content of fresh soy cheese are 3.52mg/100g, 7.04mg/100g, 5.14mg/100g, 6.20mg/100g and 10.76mg/100g respectively (Table 1). The fresh cow milk cheese contains 3.0 x 10^3 CFU/g bacteria count and 2.54 x 10^6 CFU/g fungi count while fresh soy cheese contains 2.76x 10^3 CFU/g bacteria count and 2.60x 10^6 CFU/g of fungi count (Table 1). This is similar to bacteria and fungi counts in cheese which is reported to 3.2x 10^3 CFU/g and 2.63x 10^6 CFU/g respectively for fresh cow milk cheese by Adetunji and Babalobi [7]. The fresh cow milk and soy cheeses sensory properties are 7.00 and 7.10 colour, 6.50 and 5.40 aroma, 6.50 and 7.00 taste, 6.10 and 6.50 appearance, 7.00 and 7.20 overall acceptability respectively (Table 1). Similar result has been reported for dairy products by Lee and Castle [22].

Nutritional composition of freeze dried cow milk and soy milk cheeses

The results of the effect of freeze drying on the nutritional, microbial and sensory qualities of fresh cow milk and soy cheeses are as presented in Table 2.

Table 2: Nutritional, microbial and sensory qualities of freeze dried cow milk and soy milk cheeses

Qualities	*Freeze Dried Cow Milk Cheese*	*Freeze Dried Soy Cheese*
Moisture Content (%)	*4.28±0.10*	*4.19±0.46*
Ash (%)	*32.72±0.12*	*30.98±0.55*
Protein (%)	*32.04±0.28*	*34.84±0.31*
Fat (%)	*4.05±0.98*	*4.30±0.29*
CHO (%)	*26.86±0.90*	*24.72±0.01*
K (Mg/100g)	*6.82±0.12*	*6.90±0.32*
Mg (Mg/100g)	*5.20±0.40*	*5.18±0.60*
Fe (Mg/100g)	*5.45±0.03*	*5.32±0.11*
Ca (Mg/100g)	*15.85±0.03*	*13.40±0.35*
Na (Mg/100g)	*5.20±0.40*	*5.40±0.32*
Bacterial (CFU/g)	*$2.72x10^3$±0.02*	*$2.54x10^3$±0.03*
Fungi (CFU/g)	*$2.35x10^6$±0.30*	*$2.38x10^6$±0.50*
Colour	*8.00±0.02*	*8.50±0.01*
Aroma	*8.50±0.04*	*7.20±0.02*
Taste	*8.60±0.02*	*8.20±0.70*
Appearance	*8.50±0.70*	*8.50±0.05*
Overall Acceptability	*8.80±0.02*	*9.00±0.70*

The results showed that freeze drying decreases the moisture content of fresh cow milk cheese from 54.02% to 4.28% and from 50.89% to 4.19% for soy cheese sample. Moisture content is an index of water activity, the high moisture contents of cheese will make it more susceptible to microbial contamination and thus reducing the storage time due to rapid deterioration [23]. Freeze drying is one of the most important methods developed to extend the shelf life of foods and increasing the availability of the nutrients to consumers.

Freeze drying is known to decrease the water activity of food samples, thus, protecting them against microbial activity and increases the storage life of foodstuffs. The values of water activity ensure the stability of the product against browning, lipid oxidation and enzymatic activity [24].

The results showed that freeze dried cow milk cheese and soy cheese contain 4.28% and 4.19% mean moisture respectively, this is similar to previous report by Fonseca *et al*. [25] who obtained 4.50% mean moisture for freeze dried cow milk cheese and 4.20% moisture for soy cheese. The freeze dried cow milk cheese also contain 32.72% ash, 32.04% protein and 4.05% fat while the freeze dried soy cheese contain 30.98% ash, 34.84% protein and 4.30% fat (Table 2). The result of the mineral composition of the freeze dried cow milk cheese showed that the value for the sodium, potassium, magnesium, iron and calcium content are 6.82mg/100g, 5.20mg/100g, 5.45mg/100g, 15.85mg/100g and 5.20mg/100g respectively. The sodium, potassium, magnesium, iron and calcium content of freeze dried soy cheese are 6.90mg/100g, 5.18mg/100g, 5.30mg/100g, 13.40mg/100g and 5.40mg/100g respectively (Table 2).

The freeze dried cow milk cheese contains 2.72 x 10^3 CFU/g of bacteria count and 2.35 x 10^6 CFU/g fungi count while freeze dried soy cheese contain 2.54x 10^3 CFU/g of bacteria count and 2.38x 10^6 CFU/g fungi count (Table 2). This is comparable to the report on bacterial and fungi count in cheeses which are 2.55x 10^3 CFU/g and 2.30x 10^6 CFU/g for freeze dried cow milk cheese and 2.50 x 10^3 CFU/g and 2.32 x 10^6 CFU/g in soy cheese respectively [25]. The freeze dried cow milk cheese and freeze dried soy cheese qualitative properties are 8.00 and 8.50 colour, 8.50 and 7.20 aroma, 8.60 and 8.20 taste, 8.50 and 8.50 appearance, 8.80 and 9.00 overall acceptability respectively (Table 2). Similar result has been reported for dairy products by Lenart [26].

CONCLUSION

The fresh cow milk and soy milk cheese are rich in protein, ash content, carbohydrate, calcium, potassium, magnesium, iron, quality taste, flavour, appearance, acceptability, with minimal bacteria and fungi count. The carbohydrate, protein, ash content, calcium, sodium, magnesium, taste, appearance, flavour, acceptability increased significantly ($P < 0.05$) while the moisture content, fat, bacteria and fungi count decreased significantly ($P < 0.05$) for both the cow milk and soy milk cheeses when freeze dried. The significant decreases in the moisture content as well as the bacteria and fungi counts is an indication of longer storability and extended shelf life of freeze dried cheeses if well packaged in appropriate moisture barrier packaging types. This will in turn solve the problem of deterioration of cheeses and expands its marketability in a portable form.

REFERENCES

[1] Ramakant, S.J. 2006. The efficacy of nisin can drastically vary when produced in soy cheese in model cheeses. Food Microbiology, 32: 185-190.

[2] Herrington, M.A. 2001. Production of cheese containing probiotic bacteria. Milchwissenschaft. 54: 265-268.

[3] Akinola, O.J. 2003. The place of the dairy cattle in human diet. A paper presented at a seminar organized by the Department of Animal science. Faculty of Agriculture, Ahmadu Bello University, Zaria.
[4] Andrew, K.O. 2010. Quality evaluation of cow milk, soymilk and cow/soy cheese. Journal of Diary Resources, 9:44-47.
[5] Warsama, V.O., Yadav, D.N., Sharma, G.K and Bawa, A.S. 2006. Nutritional qualities of Nigerian white cheese (wara) Nigerian Veterinary Journal, 6, 82-88.
[6] Igwe, E.C. 2002. The adoption of appropriate technology for dairy processing by Fulani nomads in Nigeria. Journal of Nomadic Studies, 5(3):61-66.
[7] Adetunji, A.O and Babalobi, E.A. 2012. Microbial quality of wara, a southwestern Nigeria soft cheese. Journal of Diary Resources, 24:74-82.
[8] Fabiyi, W.E 2006. Analysis of cheese for histamine, tyramine, histidine, tyrosine and tryptophan. Journal of Diary Science, 68: 2845 - 2846.
[9] Olatunji, E.A. 2012. Low fat white brine cheese made from bivine milk; Chemical, Physical, and Sensory attributes. International Dairy Journal, A2: 525 - 540.
[10] Adegoke, F.E., Garcia, E.A., Tomilo, J.M. 2002. Formation of biogenic amines in raw milk. Cheese manufactured with proteinases and different levels of starter culture. Journal of Food Protein, 63: 1551 - 1555.
[11] Brennan, R.A and Day, R.L. 2006. Chemical and physical methods. Standard method for the examination of Dairy products. 15th edition. America Public Health Association, Baltimore, MD. pp: 327 - 404.
[12] Osho, S.R and Dashiell, P.M. 1998. Influenced of pasteurised milk, raw milk and different ripening cultures on biogenic amine concentrations in semi soft cheeses during ripening. European Food Resources Technology, 204: 265 - 272.
[13] Lin,L.R., Vioque,M., Sanchez, E. and Mata, C. 2007. Effect of freeze drying on the sensorial characteristics of a Spanish ewe cheese. Journal of sensorial studies, 2000 (15): 251 - 262.
[14] Amano, E.A. 2013. Production of white soft cheese by rennet treatment. Journal of Diary Resources, 43, 112-118.
[15] Adetunji, V.O., Ikheba, S.A., Adedeji, A.M and Alonge, D.O. 2008. Evaluation of the bacteria in milk products sold in Southern Nigeria. Nigeria Veterinary J.24(3), 92-96.
[16] Connor, J.O. 2003. Processing and production of soy cheese; improvement, production and uses. Caldwell, B.E, (Education), American Society for Agronomy; United States America.
[17] Tofu, J.M. 2013. Modern Food Microbiology. 2nd ed. Maryland: Aspen press.
[18] AOAC (Association of Official Analytical Chemists). 2000. Official Methods of Analysis. 15th edition. Washington DC: Association of Official Analytical Chemists.
[19] AACC (American Association of Cereal Chemist). 1999. Approved Methods of the American Association of the Cereal Chemists. Saint Paul, 44-45.
[20] Compendium of Methods for the Microbiological Examination of Food. 2000. Splittstoesser Edition. Washington D.C: 423-431.
[21] Bacteriological Analytical Manual. 2002. Association of Official Analytical Chemist for Washington D.C. 14th Edition. Arlington, 71-76.
[22] Lee, H.S and Castle, W.S. 2007. Seasonal changes of carotenoid pigments and colour in Hamlin, Earlygold and Bundd. Blood orange juices. Journal of Agricultural food chemist, 49(8): 77-82.

[23] Staperelt, H., Nielsen B.R and Skibsted, H.S. 2007. Effect of heat treatment, water activity and storage temperature and the oxidative stability of dairy products. International Dairy Journal, 7: 331-339.
[24] Margues L.G and Prado M.M, 2011. Ash content of freeze dried tropical fruits. International congress on engineering and food. May 22-26, Athens, Greece, III, 2005-2006.
[25] Fonseca, L.A., Morgan, O.A and Ampatzoglou, V.B. 2001. Conventional freeze drying of cheese as a preservative technique of cheese. International Diary Journal, 5: 32-38.
[26] Lenart A.A. 2009. Colour changes of freeze dried straw berries osmotically dehydrated before drying. Food Technology operations new vistas. Monograph: 217-223.

UTICAJ PROCESA LIOFILIZACIJE NA KVALITET SVEŽEG SIRA OD KRAVLJEG I MLEKA SOJE

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Sažetak: Istražen je uticaj sušenja primenom procesa liofilizacije, na kvalitet svežeg sira od kravljeg i mleka od soje, sa ciljem da se očuvaju osobine sira u stabilnijem obliku. Uzorci kravljeg i sojinog sira pripremljeni su u svežem stanju sa dimenzijama 2 x 3 cm i debljine od 0,2 cm. Kravlji i sojin sir su podeljeni u 6 porcija težine po 100 g. Početne osobine uzoraka sireva određene su korišćenjem dela od 100 g za svaki uzorak od 500 g koji su sušeni postupkom smrzavanja.
Hranjivi, mikrobiološki i senzorni kvaliteti zamrznutih sireva određivani su standardnim metodama. Rezultati su pokazali da sveže pripremljeni sir od kravljeg mleka sadrži : 54,02% vlage, 20,34% proteina, 6,40% pepela, 18,11% masti i 4,25% ugljenih hidrata, 3,52 mg / 100 g natrijuma, 7,02 mg /100 g kalijuma, 5,22 mg /100 g magnezijuma, 6,32 mg/100 g gvožđa, 11.12mg/100g kalcijuma, $3x10^3$cfu/g bacterija and 2.54 x 10^6cfu/g gljivica. Sveže pripremljeni sojin sir sadrži: 50.89% vlage, 22.05% proteina, 6.31% pepela, 19.02% masti i 4.06% ugljenih hidrata, 3,52mg / 100g natrijum, 7.04mg /100g kalijuma, 5.14mg/100g magnezijuma, 6.20mg / 100g gvožđa, 10.76mg /100g kalcijuma, $2.76x10^3$cfu/g bacterija and 2.60 x 10^6cfu/g gljivica. Sadržaj vlage i masti u smrznutom osušenom kravljem i sojinom mleku značajno se smanjio ($P < 0,05$) sa 54,02% na 4,28%, 18,11% na 4,05% i 50,89% na 4,19%, 19,02% na 4,30%. Sušenjem primenom procesa liofilizacije značajno je smanjen sadržaj bakterija i gljivica u svežim sirevima; smanjen je sa vrednosti $3x10^3$cfu/g na vrednost 2.72 x 10^3cfu/g, 2.54 x 10^6cfu/g, na vrednosti 2.35 x 10^6cfu/g, na vrednost 2.76 x 10^3cfu/g , na vrednost 2.54 x 10^3cfu/g, 2.60 x 10^6cfu/g, na vrednost 2.38 x 10^6cfu/g za kravlje mleko i sojin mlečni sir, retrospektivno.

Sadržaj ugljenih hidrata, proteina, pepela, kalcijuma, natrijuma, magnezijuma, zatim ukus, izgleda, aroma i prihvatljivost sireva od kravljeg mleka značajno se povećava (P <0,05) kada se primeni postupak sušenja sa smrzavanjem.
Smanjenje količine vlage, broja masti i mikroba u sirevima povećava stabilnost i rok trajanja sira, ako se on pravilno pakuje.

Ključne reči: *Sir, liofilizacija, hranjive osobine, mikrobiološki kvalitet, senzorne osobine.*

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DEVELOPMENT OF A MULTI-ROLLER ABRASIVE CASSAVA PEELING MACHINE

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Abstract. A simple to operate, maintain and affordable multi-roller abrasive cassava peeling machine comprising a feed section, peeling chamber, abrasive surface, tuber discharge chute and waste peel chute was designed, fabricated and evaluated. The machine development was based on engineering standards and specification while considering crop, machine and operational factors to include the physical and mechanical properties of cassava tubers, abrasive property of peeling surface, material and speed of the machine. The machine was evaluated for performance with commonly used varieties NR 8082, 8083, 8208, 09/0581 and UMUCAS 38 having moisture content of 63.33%, 64.50%, 65.40%, 63.50% and 84.33% respectively. The performance evaluation results at a roller speed of 360rpm showed peeling efficiency of 91%, throughput capacity of 2.17kg/min, and a proportion by weight of peel of 0.9%. The cassava peeling machine fabricated, eliminated the drudgery, loss of time and tuber flesh encountered in manual peeling with better product quality when compared with the existing machines.

Key words*: Cassava variety, peeling machine, multi-roller abrasive, performance evaluation, peeling efficiency.*

INTRODUCTION

Cassava (*Manihot esculenta crantz*) is a tuberous starchy root crop of the family Euphorbiaceae [1]. It is a popular crop grown worldwide and it's known for its large deposits of carbohydrates, drought tolerance and thriving well on marginal soil.

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There is an ever increasing demand globally for the different products of cassava such as chips, pellets, starch, garri, fufu, etc of which peeling of the tubers is necessary.

Peeling is the first and a critical unit operation performed after the cassava tubers have been harvested owing to its role in the detoxification of the tubers [2].

The high demand for cassava globally as constituent of human food, and as source of foreign exchange for producing countries calls for the total mechanisation of its processes.

Cassava processing thus deserves a serious attention so as to meet the needs of the local and international community. Several unit operations of in cassava processing including; grating, boiling/parboiling, drying, milling, sieving, toasting and extrusion has been successfully mechanised [3] while peeling has remained a bottleneck globally for the design engineer. Different efforts in this field have resulted to the production of several prototypes characterised by low efficiency and low quality performance.

Several mechanism and methods in cassava peeling has been adopted. These include; steam, manual, chemical and mechanical methods with its advantages and disadvantages. Some of the efforts in the mechanical field includes; a spring loaded cassava peeling machine by [4] with efficiency of 98.8% and a 15% broken tubers; the PRODA model of cassava peeling machine made with peeling balls recorded peeling efficiency 0of 30% and much loss of the root flesh; UNN model of a batch cassava peeling made with abrasive materials loaded in a peeling drum resulted in a throughput capacity of 180kg/hr and loss of cassava tuber flesh; UNIBEN model of a cassava peeler designed at the mechanical engineering department of the University of Benin with a single tool point and fed tuber after tuber to its chuck recorded a peeling efficiency of about 25%; Cassava peeler designed and fabricated at Tamil Nudu Agricultural university, Alade (2005) revealed that the throughput capacity, peeling efficiency and peel retention were found to be 549kg/hr, 50.33% and 0.572 respectively.

In a research carried out by [5], it was discovered that the most cassava farmers/growers are small farm holders between 0.5-5 ha. As a result of this, there is need for a portable and affordable peeling machine for the cottage industries to meet their processing needs. A multi-roller abrasive cassava peeling machine was developed at the Mechanical Engineering Department, Michael Okpara University of Agriculture, Umudike, Nigeria. The purpose of this work included the following; to develop a design data base for the peeling machine; form a relationship between the cassava tubers, machine and machine operational parameters; and also to establish machine operational parameters for effective peeling of the different sizes and shapes of cassava tubers.

MATERIALS AND METHOD

Design Consideration

The machine was designed based on the following considerations so as to obtain high efficiency, portability and reliability.

1. The capacity should be higher compared to manual operation.
2. Flexibility of the parts and components of the machine and convenient servicing.
3. Ability of the machine to peel tubers of different sizes, shapes and varieties.
4. Reliability, durability and rigidity of the materials for the machine components.
5. Cost and availability of the materials.

6. Reduce loss of time and drudgery encountered in manual method.
7. Arrangement of the transmission components so as to transmit efficient power.

Machine Component Description:

The machine comprises of the following components; electric motor and gearbox, sprocket and chain drive, shafts, bearing, feed section, peeled tuber discharge chute, waste peel discharge chute, peeling rollers with abrasive surface made of emery cloth, support frame. Each of the components mentioned has one or more functions it must perform for the efficient performance of the cassava peeling machine and they include;

Electric Motor and Gearbox: The electric motor functions as the driver that powers the peeling machine while the gearbox serves as a speed reducer. The electric motor generates mechanical energy in the form of rotary motion which is transmitted using the sprockets and chain drive system.

Chain Drive and Sprocket: The sprockets and chain drive transmits the mechanical energy from the shaft of the electric motor and gearbox to the shafts of the peeling machines.

Shafts: The shafts of the cassava peeling machine transmits the mechanical energy that was generated from the electric motor and gearbox through the sprockets and chain drive system to the set of peeling rollers that uses the mechanical energy together with its abrasive surfaces to peel the cassava tubers.

Bearings: A bearing is a mechanical device that supports the shaft and reduces energy loss due to friction by eliminating friction in rubbing surfaces of the shafts and bulb.

Feed Section: This section of the machine serves as a portal through which the cassava tubers are introduced to the peeling chamber where the tubers undergo peeling action from the set of rollers that gets their action from the shaft rotation.

Peeled Tuber Discharge Chute: It is a discharge section through which the peeled tubers are collected after peeling. It can be easily assembled and disassembled from the machine.

Waste Peel Discharge Chute: This is a slanted casing through which the waste peel is let out of the peeling chamber. It is located below the peeling chamber.

Peeling Rollers and Abrasive Surface: The peeling rollers take the mechanical energy from the chain drive to peel the tubers. It is covered with emery cloth as an abrasive surface. The rotational motion of the rollers with its abrasive surface effects the peeling of the cassava tubers.

Support Frame: This holds the components of the cassava peeling machine. It serves as a shield withstanding torsional and vibrational forces occasioned by the operation of the machine.

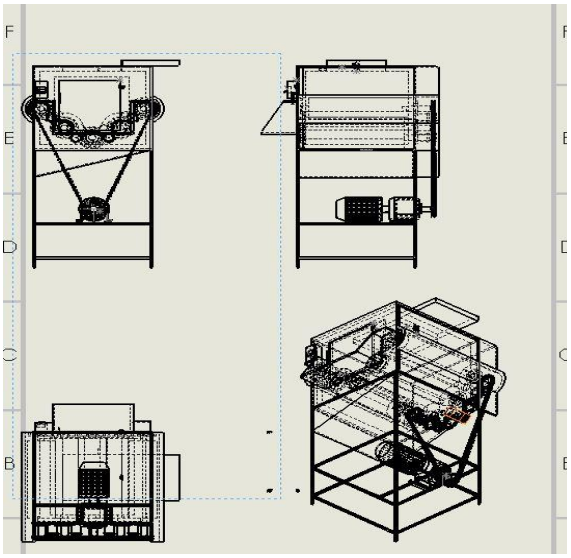

Figure 1: Orthographic View of the machine.

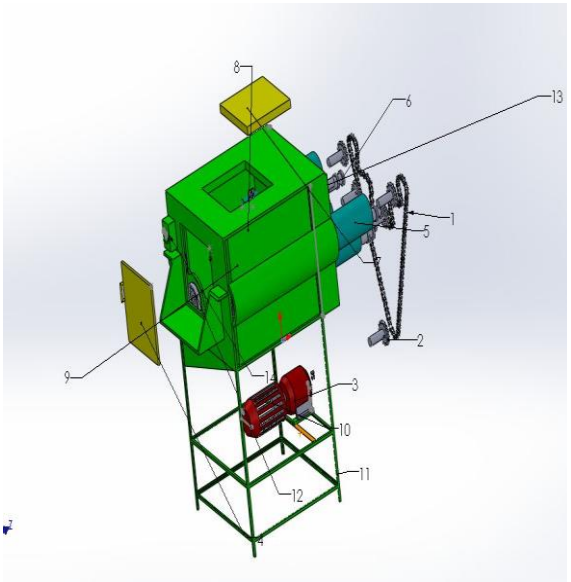

Figure 2: Isometric view of the multi-roller cassava peeling machine. Legend: 1.Chain; 2. Driver Sprocket; 3.Gearbox; 4.Outlet Chute opener; 5.Abrasive surface (Emery Cloth); 6. Idler Sprocket; 7.Feed section opener; 8.Peeling chamber; 9.Peeling Chamber; 10.Electric motor; 11.Main Fram; 12.Peeling Rollers; 13.Peeling roller driven sprocket; 14.Electric switch.

Plate 1: Pictorial view of the constructed multi-roller cassava peeling machine.

Component Design/Fabrication

Chain Drive

The transmission of the rotational motion of the electric motor to effect the needed revolutions of the peeling rollers was achieved by the use of chain drive. The parameters of the shaft of the electric motor and its sprocket were selected. Electric motor speed, N = 1440rpm; number of teeth of the electric motor shaft, $T_1 = 15$; desired number of teeth on peeling rollers sprockets, $T_2 = T_3 = T_4 = T_5 = T_6 = 15$.

To achieve the desired speed of the peeling rollers, an integral gearbox of transmission ration 4:1 was integrated with the electric motor.

The Design power P_D, of the chain drive was determined as given by [6];

$$P_D = P_R \times S_F \quad (1)$$

Where; P_R = rated power of motor,

$$S_F = S_1 \times S_2 \times S_3 \quad (2)$$

Service factor S_1, S_2, S_3 for constant loading, periodic lubrication and continuous service respectively [6]; [7]; [8].

For a complex chain drive involving five (5) driven sprockets of the peeling rollers and the sprocket of the electric motor-gearbox, he entire legth of chain was sectioned into five (5) sections L_1, L_2, L_3, L_4, and L_5.

First section is formed by the driving sprocket and the first (lowest) driven sprocket with centre to centre distance x_1 = 300mm while the sections connecting the driven sprockets have centre to centre distances of x_2, x_3, x_4, x_5 = 130mm.

To transmit the design power as calculated above, a chain type no 10 with two stands, pitch p, roller diameter d, minimum with of roller w, of 15.875mm, 10.16mm, and 9.65mm (Table 21.1 and Table 21.4 of [6] respectively can be used.

The length of the chain as sectioned was determined with the formula suggested by [6] and [8]);

$$L_1 = K_1 \text{ x } p \quad (3)$$

$$L_2 = K_2 \text{ x } p \quad (4)$$

Where;

K_1 = chain link formed by the driver sprocket and the first driven sprocket.

$$= \frac{T_1 + T_2}{2} + \frac{2\ x_1}{p} + \left(\frac{T_2 - T_1}{2\pi}\right)^2 x\ \frac{p}{x_1} \quad [6] \quad (5)$$

X_1 = centre distance of the first chain section.

$$K_2 = \frac{T_2 + T_3}{2} + \frac{2\ x_2}{p} + \left(\frac{T_3 - T_2}{2\pi}\right)^2 x\ \frac{p}{x_2}\ [6] \quad (6)$$

$x_2 = x_3 = x_4 = x_5$ = centre distance of the driven sprockets

K_2, K_3, K_4, K_5 = chain link between the driven sprockets.

$L_2 = L_3 = L_4 = L_5$

While the entire length L, of the chain was gotten as

$$L = L_1 + 4L_2 \quad (7)$$

Average Speed of the Chain

The pitch circle diameter, d_1 and average speed of the chain which is the chain pitch line velocity, V on the sprockets were determined as 76.36mm 14.39m/s using equations 7 and 8 as given by [6] and [8].

$$d_1 = \text{p x cosec x}\left(\frac{180}{T}\right) \quad (8)$$

$$V = \frac{\pi\ x\ d_1\ x\ N}{60} \quad (9)$$

Where; T = number of teeth of the sprockets, 15

N = speed of the sprockets, 360rpm

Angle of Articulation

The angle of articulation, θ/2 through which the links swings as it enters contacts with the sprockets teeth was determined as 12^0 using equation 9 by [6] and [8]);

$$\theta = \frac{360}{T} \quad (10)$$

2.3.6 Selection of Drive Shafts

The shaft diameters, D of the peeling rollers of this machine were determined using maximum stress relations given by [7]; [8] and [6] in equation 10 as;

$$D = \left[\frac{16}{\pi\ \tau}\left(\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right)\right]^{\frac{1}{3}} \quad (11)$$

Where;
τ = Allowable shear stress for steel shaft with provision for key ways, (42 N/mm)

M_t = Maximum Twisting Moment on the shafts, N-mm
M_b = Maximum Bending Moment on the shafts, N-mm
K_b = Combined shock and fatigue factor for bending, 2
K_t = Combined shock fatigue factor for twisting, 1.5

Selection of Prime Mover

The power, p required for the operation of this machine is the power required to drive the shaft of the speed reducer which then drive the shaft on the peeling rollers. The power in watts required to drive this machine was determined as 1.474 HP (1.100kw) using equation 12.

$$P = \frac{2\pi NT}{60} \quad (12)$$

Where; P = Power to drive the machine in watts
N = Output speed of the speed reducer and peeling rollers
T = Twisting moment on the output shaft of the speed reducer, 29.58 N-m

Taking care of 10% possible loss due to friction [9], the power required to drive the multi-roller abrasive peeling machine was computed from equation 11 1.100Kw (1.474 HP). Therefore, (2HP) electric motor which can be powered using a 3 phase electric power supply was selected for this cassava peeling machine.

Machine Operation

The machine was evaluated for performance in terms of throughput capacity, T_C, proportion of weight of peel, P, and peeling efficiency μ. The throughput was measured in terms of mass of tubers per batch of peel per unit time.

The peeling chamber was filled with different batch sizes of 5kg, 10kg, 15kg, and 20kg of different varieties of cassava (NR 8082, 8083, 8208, 09/0581 and UMUCAS 38). The time of peel, mass of peeled tuber, mass of waste peel were duly noted during the test. The throughput capacity, T_C, proportion of weight of peel, P, and peeling efficiency μ, were gotten from the expression given by [10];

$$T_C = \frac{M_C}{T} \quad (13)$$

$$P = \frac{M_{PC}}{M_S} \quad (14)$$

$$\mu = \frac{M_{PC}}{M_{PR} + M_{PC}} \text{ (Aggarwal, 1987)} \quad (15)$$

RESULTS AND DISCUSSION

Table 1: The machine design technical parameters

Technical/Calculated Parameters	Symbol	Value	Unit
Chain Length	L	2.8	m
Angle of Articulation	$\theta/2$	12^0	Radians
Design power of the chain	P_D	2.475	kW
Average Speed of chain	V	14.39	m/s
Power required	P	2	Hp
Shaft speed	N_2	360	rpm
Diameter of peeling roller shafts	D	0.46	m
Maximum mass of cassava tubers per batch of peel	M	24	kg
Maximum bending moment on the peeling roller shafts	M_b	1.61, 0.89, 0.23	Nm
Effective volume of peeling chamber	V_{PC}	0.072	m^3

Table 2. Varieties and parameters for performance evaluation

Type	Time of peel, T (min)	Weight of tuber before peeling Ms (kg)	Weight of completely peeled tuber Mc (kg)	Mass of peel Mp (kg)	Weight of peeled tuber Mpc (kg)	Weight of peel removed by hand Mpr	Tuber loss M_F (kg)
NR	2	5	1.20	0.6	4.35	0.60	0.05
8082	4.01	10	3.99	1.29	8.50	1.29	0.21
	7.32	15	4.94	1.58	13.16	1.58	0.26
	10.10	20	7.44	2.59	17.10	2.59	0.31
NR	1.98	5	1.2	0.82	4.10	0.82	0.08
09/058	3.92	10	3.42	1.62	8.20	1.62	0.18
1	7.25	15	3.44	1.98	12.80	1.98	0.22
	10.00	20	6.96	2.21	17.50	2.21	0.29
UMUC	2.10	5	1.71	0.70	4.21	0.70	0.09
AS 38	4.12	10	2.82	0.82	9.00	0.82	0.18
	7.10	15	5.28	1.63	13.15	1.63	0.22
	9.53	20	3.85	2.35	17.36	2.35	0.29
NR	2.01	5	1.28	0.60	4.34	0.60	0.60
8083	3.96	10	4,01	1.30	8.49	1.30	0.21
	7.28	15	4.86	1.57	13.12	1.57	0.31
	10.04	20	7.35	2.58	17.00	2.58	0.42
NR	2.05	5	1.21	0.86	4.02	0.86	0.12
8082	4.02	10	3.56	1.57	8.22	1.57	0.21
	7.94	15	3.87	1.80	12.74	1.80	0.41
	9.92	20	6.92	2.17	17.46	2.17	0.37

Table 3. Performance evaluation result of the multi-roller cassava peeling machine

Type	Ms	Prop. by weight P (kg)	Peeling effic. (μ)	Mech. damage (λ)	Peel retention (PR)	Quality perform. efficiency (Ω)	Throughput Capacity Tc (min)
NR 8082	5	0.87	0.87	0.04	0.03	0.96	2.17
	10	0.85	0.86	0.05	0.04	0.95	2.11
	15	0.87	0.89	0.05	0.05	0.95	1.79
	20	0.85	0.86	0.04	0.03	0.96	1.69
NR 09/0581	5	0.82	0.83	0.06	0.04	0.93	2.07
	10	0.82	0.83	0.05	0.04	0.95	2.09
	15	0.85	0.86	0.06	0.05	0.93	1.76
	20	0.87	0.88	0.04	0.03	0.96	1.75
UMUCA S38	5	0.84	0.85	0.05	0.04	0.95	2.00
	10	0.90	0.91	0.06	0.05	0.94	2.18
	15	0.87	0.88	0.04	0.03	0.96	1.80
	20	0.86	0.88	0.07	0.06	0.92	1.82
NR 8083	5	0.86	0.87	0.04	0.03	0.95	2.15
	10	0.84	0.86	0.04	0.03	0.95	2.14
	15	0.87	0.89	0.05	0.04	0.94	1.80
	20	0.85	0.86	0.05	0.04	0.94	1.69
NR 8082	5	0.80	0.82	0.09	0.07	0.90	1.96
	10	0.82	0.83	0.05	0.04	0.94	2.04
	15	0.84	0.87	0.09	0.07	0.90	1.60
	20	0.87	0.88	0.05	0.04	0.94	1.76

Table 4. Bill of engineering measurement and evaluation (BEME)

S/N	Component part	Material used	Qty	Rate	Amount(₦)
1	Electric motor	2 HP 3-phase	1	-	40000
2	Frame	Mild steel angle iron 2x2	3	2500	7500
		Mild steel angle iron 1x1	2	1000	2000
3	Bearing	Mild steel	10	800	8000
4	Bolts and nuts	Mild steel	16	80	1280
5	Plate	Mild steel 2mm	1	-	15200
		Mild steel 10mm	1	-	30000
6	hinges	Mild steel	2	150	300
7	Pulley	Mild steel	4	900	3600
8	Sprockets	Carbonised mild steel	6	1500	9000
9	Rollers	Hardened mild steel	5	6520	32600
10	Shaft	Hardened mild steel	5	2530	12650
11	Chain	Medium carbon	1	5200	5200
12	Paint	Red oxide, green	-	-	11000
13	Transportation	-	-	-	15000
14	Labour	-	-	-	60000
15	Miscellaneous	-	-	-	29320
	Total	-	-	-	**282650**

Results of this research work are presented in Tables 1- 4. Table 1 reveals the machine design technical parameters.
According to the results, the power requirement of the machine is 1.464 kW which entails that 2 HP electric motor with speed of 1440 rpm will power the machine.
This power is transmitted to the shafts bearing the peeling rollers that peel the cassava tubers with an abrasive surface (emery cloth). The peeling rollers rotate at a speed of about 360 rpm.
Tables 2 and 3 present the machine performance results. From the results as recorded in these tables, it is observable that the machine attains peeling efficiency of up to 91% at minimum average flesh loss of 0.195 kg for Umucas 38 variety with highest moisture content.
This is an indication that moisture content favours the developed multi-roller abrasive peeling.
From the bill of engineering measurements and evaluation, as recorded in Table 4, the total cost of the fabrication of the machine is two hundred and eighty two thousand, six hundred and fifty naira only (N282,650.00).

CONCLUSION

The need for pre-operation such as cutting of the cassava tuber with depressed sections, tuber stumps, and washing of the tubers before peeling in order to have an effective operation poses a great limitation. However, an improvement can still be made so as to eliminate the time expended in preoperational activities. The Developed cassava peeler recorded high peeling efficiency of 91% and throughput of 2.71 kg/min for variety having highest moisture content, hence revealing that the machine performs better with freshly harvested tubers (with high moisture content) The cassava peeler produced is a prototype therefore can only contain about 24 kg of cassava at a time. However it can be improved upon by scaling up the peeling chamber capacity for industrial purposes. To increase the capacity of the machine, the time taken to cut the depressed parts and shrubs should be eliminated. Further research could be carried out on the Production of a more advanced machine that will take care of the stump and depressed part.

REFERENCES

[1] Kochlar, S. L (1981), Tropical crops: A textbook of economic botany: Macmillan Publishers Ltd, pp. 467.
[2] Opara, L. U (1999). Yam storage. In CIGR Handbook of Agricultural Engineering Volume IV: Agro Processing. The American Society of Ag. Engineers, ST Joseph, MI. 182-214.
[3] Ezekwe, G. O (1976); "A feature for achieving a constant depth of peel in the mechanical peeling of cassava"; Nigeria Journal of Engineering, Volume 1, Issue 3, pp.174-181.

[4] Adetan, D.A., Adekoya, L.O., Aluko, O.B. & Makanjuola, G.A. (2005), ‘’An Experimental Mechanical Cassava Tuber Peeling Machine’’, Journal of Agricultural Engineering and Technology (JAET). 13, 27-34.
[5] Howeler, R. H; Watananouta, W; Tran Ngoc Ngoan (2004); “Farmers decide. A participatory approach to development and dissemination of improved cassava technology that improve yield and prevent soil degradation.” Proceedings of 13th International Society of Tropical Root Crops held in Arusha Tanzania.
[6] Khurmi, R. S and Gupta, J. K, 2012. A textbook of machine design. Published by S. Chand and Company.
[7] Bur, A. H; Cheathan, J. B (2002) Mechanical; Analysis and Design (2nd Edition) Prentice Hall Publishers, New Delhi.
[8] Sharma, P. C, Aggarwal D. K; A textbook of machine design. S. K Katara and Sons Publishers, New Delhi (2009).
[9] Nwankwojike, B. N. (2012). Angle of Repose of Digested Oil Palm Fruit Mash and Pulp on Steel. *Int. Jour. of Innovative Technology & Creative Eng.. Vol .2 No.2 pp 12 – 17.*
[10] Olukunle, O.J and Akinnuli, B.O. (2012) “Performance Evaluation of a Single Action Cassava Peeling Machine” Federal University of Technology, Akure (FUTA).

RAZVOJ ABRAZIVNE MULTI ROLER MAŠINE ZA LJUŠTENJE CASSAVA KRTOLA

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Sažetak. Dizajnirana, izrađena i ocenjena kao jednostavna za rukovanje, održavanje i pristupačna brusna mašina sa multi-valjcima za ljuštenje Cassava krtola (*Manihot esculenta crantz*), koja se sastoji od: prijemnog koša, komora za ljuštenje, abrazivne površine valjka, kanala za ispuštanje krtola i otpada. Razvoj mašine je zasnovan na inženjerskim standardima i specifikacijama uz razmatranje osobina Cassava krtole, mašine i radnih parametara koji uključuju fizička i mehanička svojstva Cassava krtola, abrazivnih osobina površine ljuštenja, materijala i brzine rotora mašine. Mašina ima procenjene performanse za uobičajeno korišćene Cassava varijetete: NR 8082, 8083, 8208, 09/0581 i UMUCAS 38 sa sadržajem vlage od 63,33%, 64,50%, 65,40%, 63,50% i 84,33% retrospektivno. Rezultati analize performansi mašine kod brzine valjka od 360 min^{-1} pokazali su: efikasnost ljuštenja od 91%, propusni kapacitet od 2,17 kg/min, sa udelom težine kore od 0,9%. Prikazna mašina za ljuštenje krtola kasave, eliminisala je gubitak vremena i mase krtole koji se pojavljuje kod ručnog ljuštenja krtola, sa boljim kvalitetom proizvoda u poređenju sa postojećim mašinama.

Ključne reči: *Cassava varijeteti, mašina za ljuštenje, abrazivni multi roler valjci, ocena performansi, efikasnost ljuštenja.*

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ANALIZA STANJA TOČKOVA VILJUŠKARA U EKSPLOATACIJI

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Sažetak: Cilj rada je analiza ispravnosti, odnosno stanja točkova viljuškara. Prikazana je metodologija istraživanja koja se koristila za analizu stanja gume na točkovima viljuškara, i to metodom deskripcije pomoću ček-liste. Istraživanje je sprovedeno na uzorku od 127 viljuškara prosečne starosti 15-tak godina, pri čemu je utvrđeno da na oko 15% viljuškara postoji problem korišćenja preterano istrošenih i/ili mehanički oštećenih točkova. Dobijeni rezultati istraživanja ispravnosti točkova viljuškara su prodiskutovani i predložena su dalja istraživanja.

Ključne reči*: viljuškari, guma na točkovima, metodologija, istraživanje, analiza, ček-lista.*

UVOD

Opstanak, funkcionisanje i uspešan rad nekog preduzeća obezbeđuju kvalitetni tokovi energije, informacija, a pogotovo tokovi materijala. U osnovne elemente procesa proizvodnje spadaju obrada, transport i skladištenje, koji omogućavaju tokove materijala, a samim tim i proces proizvodnje. Pojam transport podrazumeva premeštanje predmeta transporta sa jednog na drugo mesto korišćenjem jednog ili više transportnih sredstava.

Transport se prema mestu i ulozi u privredi deli na: spoljni transport (ulazni/izlazni) koji se obavlja od dobavljača do naručioca i od proizvođača do potrošača, unutrašnji transport koji služi za prevoz materijala i/ili (polu)proizvoda unutar preduzeća i integralni transport koji obuhvata premeštanje predmeta transporta od početnog mesta proizvodnje do krajnjeg potrošača. [1]

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Vozilo unutrašnjeg transporta je namenjeno za: prenošenje tereta na kraćim rastojanjima (od par metara do par stotina metara), kretanje po podu bez šina, javnom putu ili terenu van uređenih puteva, nošenje, a često i za dizanje, slaganje i spuštanje, prihvatanje i odlaganje tereta zahvatnim sredstvom najčešće u obliku viljušaka ili platforme. [2]

Viljuškari spadaju u podizna vozila unutrašnjeg transporta, koja se koriste za podizanje, spuštanje i prenošenje tereta na kratka rastojanja u horizontalnom i vertikalnom pravcu, pretovarne radove, skladištenje i transport. [3]

Najznačajnije opasnosti/štetnosti pri radu sa viljuškarima su nedovoljna bezbednost rotirajućih i/ili pokretnih delova, mogućnost spoticanja ili klizanja, rad na visini, pad tereta, prevrtanje, kretanje vozila unutrašnjeg transporta, štetni klimatski uslovi (rad na otvorenom) i nefiziološki položaj tela. Uzročnik povrede pri radu sa viljuškarima jeste prevrtanje i sudar.

Poznata je činjenica da u svetu svake godine veliki broj radnika pogine ili se povredi pri radu sa viljuškarima. Prema [4], zvanični podaci objavljeni od strane OSHA (Occupational Safety and Health Administration) ističu da se pri radu sa viljuškarima godišnje u SAD dogodi 96.785 nezgoda, od toga 61800 manjih nezgoda, 34.900 ozbiljnih nezgoda i 85 nezgoda sa smrtnim povredama. Upoređujući ukupan broj viljuškara (855.900) u SAD sa ukupnim brojem povreda na radu saznajemo da je očekivano da će 11% viljuškara učestvovati u manjim ili većim nezgodama.

Najčešće smrtne povrede pri radu sa viljuškarima su: priklještenje zbog prevrtanja vozila (42%), priklještenje između vozila i površine (25%), priklještenje između dva vozila (11%), udar ili gaženje radnika viljuškarom (10%), udar zbog padajućeg materijala (8%) i pad sa platforme na viljuškaru (4%). [4,5]

Za bezbedan rad viljuškara neophodno je da se pored redovne provere ispravnosti parkirne (ručne) i radne (nožne) kočnice, svetlosne i zvučne signalizacije, krajnjeg isključivača za zaustavljanje viljuški u krajnjem gornjem položaju vrši i provera kontakktne površine na točkovima (guma) viljuškara preterano istrošene i/ili mehanički oštećene.

Postoje sledeće vrste guma na točkovima viljuškara i to: pneumatske (pumpane ili vazdušne gume), superelastik (pune gume), cushion (nalivene gume) i gume za magacinske viljuškare. Viljuškari koji se koriste za vožnju po neravnim i grubim površinama treba da poseduju točak sa pneumatikom. Točak sa punom, tvrdom gumom, [6] treba da imaju viljuškari namenjeni za vožnju po glatkim površinama i magacinima.

MATERIJAL I METODE RADA

Definisanje problema istraživanja

U literaturi [2], se naglašava da rukovalac/vozač svakodnevno mora da kontroliše stanje točkova viljuškara, a posebno istrošenost i oštećenja gazećeg sloja i bokova pneumatika, kao i naplatka točka. Problem istraživanja je nedostatak aktuelnih saznanja o stanju, odnosno ispravnosti točkova viljuškara.

Na osnovu dugogodišnjeg iskustva prilikom periodičnih pregleda i provera uočeno je da kod određenog broja viljuškara postoji prekomerna istrošenost i/ili mehanička oštećenja kontaktne površine točkova.

U dostupnoj domaćoj i stranoj literaturi nisu pronađena istraživanja koja obuhvataju prethodno istaknut problem.

Cilj istraživanja

Osnovni cilj istraživanja je da se u posmatranim preduzećima utvrdi koliko je procentualno učešće viljuškara sa preterano istrošenim i/ili mehanički oštećenim pneumaticima na točkovima u odnosu na ukupan broj analiziranih viljuškara. Poseban cilj istraživanja je utvrditi vrste i uzroke preterane istrošenosti i/ili mehaničkih oštećenja točkova viljuškara.

Hipoteza istraživanja

Pretpostavlja se da je kod više od 10% analiziranih viljuškara prisutna preterana istrošenost i/ili mehanička oštećenja točkova viljuškara.

Metode istraživanja

U postojećim ček-listama u Republici Srbiji uglavnom su ponuđeni odgovori DA/NE, gde se u nekim pitanjima za opasno stanje daje odgovor DA, a u nekim pitanjima odgovor NE, te je preglednost na nezavidnom nivou. Predloženo je da se u novoformiranoj ček-listi ponude odgovori „opasno“, „nebitno“ i „bezbedno“. Nakon popunjavanja ček-liste, za odgovore tipa „opasno“ moraju se predložiti odgovarajuće korektivne mere. [1,7] Na osnovu ček-lista za dnevnu proveru ispravnosti viljuškara [8,9,10] i stručnih nalaza za periodične preglede i provere viljuškara postavljena su pitanja u novoformiranoj ček-listi za analizu stanja bezbednosti čeonog viljuškara. Za dokazivanje ili opovrgavanje hipoteze istraživanja korišćena je deskriptivna metoda, odnosno postupak opisivanja putem davanja komentara na postavljena pitanja. Primer popunjene ček-liste za analizu stanja bezbednosti čeonog viljuškara dat je u tabeli 1. U radu će se dalje komentarisati samo pitanje broj 15, odnosno dati analiza stanja točkova viljuškara.

Uzorak istraživanja

Istraživanjem je obuhvaćen uzorak od 127 viljuškara, prosečne starosti oko 15 godina za koje su prikupljeni i analizirani podaci o stanju pneumatika na točkovima viljuškara. Istraživanje je trajalo dva meseca (maj-jun 2017. godine) i sprovedeno je u 46 preduzeća na teritoriji opština: Novog Sada (83 viljuškara), Bečeja (25), Temerina (12) i Beočina (7). Dizel motor kod viljuškara je bio zastupljen sa 50% od ukupnog broja, ili 62 komada, dok je sa električnim motorom bilo 34, i sa motorom na gas, ukupno 31.

Tabela 1. Analiza stanja bezbednosti čeonog viljuškara
(OP – opasno, NB – nebitno, BZ – bezbedno)
Table 1. Analysis of the safety state of counterbalanced forklifts
(D – dangerous, N/R – not relevant, S – Safe)

ANALIZA STANJA BEZBEDNOSTI ČEONOG VILJUŠKARA *ANALYSIS OF THE SAFETY STATE OF COUNTERBALANCED FORKLIFTS*					28	12.05.2017.
Ime i sedište poslodavca *The name and seat of employer*						
Delatnost (oblast u kojoj privređuje) Industry (business area)			Proizvodnja drvene ambalaže *Manufacture of wooden packaging*			
Vrsta opreme *Type of equipment*	ČEONI VILJUŠKAR *COUNTERBALANCED FORKLIFTS*		Pogon *Drive*		Dizel *Diesel*	
Proizvođač *Manufacturer*	LINDE		Godina proizvodnje *The year of production*		1998.	
Tip / model *Type / model*	H 25		Nosivost u tonama *Load capacity in tons*		2.5	
Redni broj *Ordinal number*	Pitanje *Question*	Komentar *Comment*	OP *D*	NB *N/T*	BZ *S*	Preporučene mere *Recommended measures*
1.	Konstrukcija kabine / zaštitnog krova *Overhead guard*	Konstrukcija zaštitnog krova je u dobrom stanju. Nema vidljivih oštećenja, napuknuća i slično. Ima unutrašnji retrovizor. *Construction of protective roof is in good condition. No visible damage, cracks or similarly. It has an internal mirror.*				
2.	Prilaz do mesta upravljanja (kontakt u tri tačke – stepenik i rukohvati) *Access to the forklift seat (three-point contact – step and handrails)*	Postoji stepenik i rukohvat na delu ramovske konstrukcije. *There is a step and a handrail on part of the frame structure.*				
3.	Sredstva za prihvatanje tereta (viljuške ili neko drugo sredstvo,	Teleskop nije iskrivljen niti napukao. Viljuške su oštećene i postoje klinovi				

	osigurač viljuški – opruga ili klin) i teleskop *Forks (fuses forks - spring or wedge) and telescope*	za levi i desni krak viljuški) *The telescope is not distorted or cracked. The forks are damaged and there are wedges for left and right part of forks.*				Ugraditi nove viljuške *Install new forks*
4.	Upravljački mehanizam *Control mechanism*	Sprečavanje neovlašćenog korišćenja postoji u vidu ključa uklonjenog iz kontakt brave. *Prevention of unauthorized use is in the form of a key removed from the ignition switch.*				
		Sve upravljačke komande su ispravne. *All control commands are correct.*				
		Uređaj za uključenje u slučaju nevolje nije ugrađen *The emergency switch is not installed.*				
		Postoji nalepnica sa oznakama komandi *There is a sticker with command labels.*				
5.	Krajnji isključivač (prelivni ventil) za ograničenje podizanja *Limit switch (overflow valve) to limit lift*	Krajnji isključivač je u funkciji, automatski se zaustavlja podizanje viljuški u krajnjem gornjem položaju. *The limit switch is in operation, it automatically stops lifting the forks in the up position.*				
6.	Zvučna signalizacija *Sound signaling*	Viljuškar je opremljen ispravnom zvučnom signalizacijom. *The forklift is equipped with the correct sound signaling.*				
		Alarmni uređaj za kretanje unazad (zvučno upozorenje kod vožnje				Ugraditi uređaj za kretanje

		unazad) nije ugrađen. *Reverse alarm device (audible warning when reversing) is not installed.*				unazad *Install a reverse alarm device*
7.	Svetlosna signalizacija *Light signaling*	Ne postoji rotaciono svetlo. *There is no rotary light.*				
		Postoji ispravno prednje svetlo. *It exists correctly headlight.*				
		Ne postoji zadnje svetlo. *There is no tail light.*				
		Svetla pokazivača pravaca nisu ugrađena. *Direction indicator lights are not installed.*				
8.	Parkirna kočnica *Parking (hand) brake*	Parkirna (ručna) kočnica je u funkciji. *The parking brake is operational.*				
9.	Radna kočnica *Service (foot) brake*	Radna (nožna) kočnica je u funkciji. Viljuškar se zaustavlja pritiskom na nožnu kočnicu (mehanički princip kočenja) i puštanjem gas papučice (elektronski princip kočenja). *The service (foot) brake is operational. The forklift is stopped by depressing the foot brake (mechanical brake principle) and releasing the accelerator pedal (electronic brake principle).*				
10.	Hidraulički uređaji *Hydraulic devices*	Hidraulika za podizanje viljuški, kao i za promenu nagiba jarbola funkcioniše besprekorno. Nema curenja tečnosti niti ulja ispod viljuškara. *The hydraulics for lifting the forks as well as for*				

		changing the pitch of the mast work flawlessly. There is no liquid leakage or oil under the forklift.				
11.	Dijagram nosivosti *Load capacity chart*	Nalepnica sa grafičkim prikazom dijagrama nosivosti je neoštećena i sa čitljivim podacima. *The sticker with a graph showing the load chart is undamaged and with legible data.*				
12.	Pločica sa opštim i tehničkim podacima *Date plate*	Metalna pločica sa opštim i tehničkim podacima je na mestu, neoštećena i sa čitljivim podacima. *Metal plate with general and technical data is in place, undamaged and with legible data.*				
13.	Natpisi – oznake obaveštenja, upozorenja I zabrane (nalepnice) *Safety and Warning Decals*	Nalepnice su neoštećene. *The decals are undamaged.*				
14.	Sigurnosni pojas *Seat belt*	Sigurnosni pojas ugrađen i ispravan . *The seat belt is fitted and is correct.*				
15.	Točkovi /Gume *Wheels and Tires*	Zadnja levi točak sa punom gumom ima velika mehanička oštećenja. Točkovi su u ispravnom stanju, nema iskrivljenja i vijci za pričvršćivanje točkova su pritegnuti i na svom mestu. *The rear wheel left Solid Tire has great mechanical damage. The wheels are in good working order, there is no distorting and the wheel mounting bolts are tightened in place.*				Zameniti zadnji levi točak sa punom gumom *Replace left rear wheel with -Solid Tire*

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Rezultati istraživanja koji se odnose na ispravnost točkova viljuškara dati su u tabeli 2. Na osnovu dobijenih podataka uočava se da je postavljena hipoteza istraživanja dokazana, odnosno da je potvrđeno da je kod 14,7% analiziranih viljuškara prisutna neusaglašenost koja se odnosi na ispravnost točkova, što je više od pretpostavljenih 10%. Kod svih analiziranih viljuškara nije utvrđena neispravnost točkova.

Tabela 2. Rezultati istraživanja ispravnosti točkova viljuškara

Table 1. The results of the analysis of proper functioning of weels on forklift wheels

	BROJ VILJUŠKARA / NUMBER OF FORKLIFT							
	Opština / *Municipality of*				Ukupan broj viljuškara / *odgovora* *Total number of forklifts / Answers*	Broj negativnih (opasnih) odgovora *Number of negative (dangerous) answers*		*%*
	Novi Sad	*Bečej*	*Temerin*	*Beočin*				
	83	25	12	7				
Točkovi / puna guma *Wheels/ Solid Tires*	11	3	0	2	127	16	18	14,7
Točkovi sa pneumatikom *Wheels/ Pneumatic Tires*	0	2	0	0		2		

Na istom uzorku od 127 viljuškara, kod 58,27% (74) analiziranih viljuškara prisutna je neusaglašenost koja se odnosi na označavanje upravljačkih komandi, [1]. Prema [2], kod analiziranih viljuškara izraženiji je problem nepostojanja ispravnog alarmnog uređaja za kretanje unazad (54,33%) u odnosu na neispravnost zvučne sirene (26,77%).

Od ukupnog broja analiziranih viljuškara (127) pune gume ima 100 viljuškara što iznosi 78,74%. Pneumatske gume ima 27 viljuškara što iznosi 21,26% od ukupnog broja.

Uzorci zamene guma kod viljuškara su: pored preterane istrošenosti gazećeg (površinskog) sloja gume ispod granične (sigurnosne) linije i raznovrsna mehanička oštećenja guma, kao što je stvaranje sitnih pukotina u površinskom delu gume, pucanje površinskog sloja gume, cepanje površinskog dela gume i radijalno pucanje – pucanje zida gume.

Primeri mehaničkih oštećenja točkova viljuškara dati su na slici 1. Radijalno pucanje tvrde gume točka (pucanje zida pneumatika) prikazano je na slici 1/a, a na slici 1/b je prikazano „otpadanje“ većeg komada gume sa točka. Cepanje gume, oštećenje bočnog zida gume i „otpadanje“ većeg komada gume sa točka, prikazano je na slici 1/c.

Pored prethodno utvrđenih mehaničkih oštećenja na svim prikazanim točkovima uočava se preterana istrošenost gazećeg (površinskog) sloja točka.

a) b) c)

Slika 1. Primeri mehaničkih oštećenja na točkovima viljuškara (sopstveni izvor)
Figure 1. Examples of mechanical damage on forklift wheels (own source)

U cilju produženja radnog veka točkova viljuškara neophodno je da rukovalac/vozač izbegava oštra agresivna skretanja, prevelike brzine, nagla kočenja/ubrzavanja, vožnju po oštećenim putevima i prelazak preko oštrih predmeta i prepreka. Zamenu točkova viljuškara sa pneumaticima ili sa tvrdom gumom, obavlja rukovalac/vozač viljuškara na način propisan uputstvom za upotrebu, održavanje i bezbedan rad.

ZAKLJUČAK

U radu je data analiza ispravnosti, odnosno stanja točkova viljuškara, koji su zajedno sa dizalicama i trakastim transporterima najzastupljenija transportno-pretovarna sredstva.

Analiza ispravnosti točkova je urađena na odabranom uzorku od 127 viljuškara, pri čemu je utvrđeno da na 18 (14,7%) viljuškara od ukupno analiziranog broja postoje mehanička oštećenja i/ili prevelika istrošenost kontaktnih površina na točkovima viljuškara.

Istraživanje obavljeno deskriptivnom metodom korišćenjem novoformirane ček-liste za analizu bezbednosti na posmatranom uzorku predstavlja značajan doprinos u dobijanju podataka koji se odnose na ispravnost hodnog sistema viljuškara.

Dalja istraživanja treba usmeriti na analizu ispravnosti točkova viljuškara na mnogo većem uzorku da bi se dobili relevantniji podaci. Takođe, istraživanje treba proširiti tako da se obuhvate i sva preostala pitanja iz novoformirane ček-liste Analiza stanja bezbednosti viljuškara.

Predlaže se korišćenje novoformirane ček-liste: Analiza stanja bezbednosti viljuškara za utvrđivanje da li su ispunjene propisane mere zaštite kod viljuškara, a u sve u cilju jednostavnijeg, bržeg i efikasnijeg uočavanja određenih neispravnosti koje utiču na bezbedan rad sa viljuškarima.

Da bi se smanjio broj nezgoda pri radu sa viljuškarima neophodno je primenjivanje i sprovođenje preventivnih mera, kao što je stručno osposobljavanje svih rukovalaca/vozača viljuškara i svakodnevna provera ispravnosti viljuškara.

Važan zahtev bezbednosti pri radu sa vozilima unutrašnjeg transporta glasi:
samo stručno osposobljeni rukovaoci/vozači mogu upravljati ispravnim, bezbednim viljuškarima.

LITERATURA

[1] Gavanski, D. 2019. *Analiza označavanja upravljačkih uređaja viljuškara*. Objavljeno u: 14. Međunarodno savetovanje na temu Rizik i bezbednosni inženjering. pp. 159-165. Kopaonik, Republika Srbija: Visoka tehnička škola strukovnih studija u Novom Sadu. Dostupno na: http://www.rizik.vtsns.edu.rs/wp-content/uploads/2019/03/Zbornik-RIZIK-2019.pdf [datum pristupa: 22.01.2020.]

[2] Šostakov, R., Zelić, A., Živanić, D. 2019. *Bezbednost i zaštita na radu sa mašinama unutrašnjeg transporta.* pp. 161,179. Novi Sad, Republika Srbija: Univerzitet u Novom Sadu, Fakultet tehničkih nauka.

[3] Nikolić, B., Gavanski, D. 2006. *Priručnik za obuku rukovaoca viljuškarom*. pp. 13. Novi Sad, Republika Srbija: Viša tehnička škola u Novom Sadu.

[4] *National Forklift Safety Day is June 10th*. Dostupno na: http://forkliftsystems.com/national-forklift-safety-day-is-june-10th/ [datum pristupa: 22.01.2020.]

[5] *Forklift Safety: Facts, Stats and Tips for Safe Operation [Infographic]*. Dostupno na: https://www.optimumsafetymanagement.com/blog/forklift-safety-infographic/ [datum pristupa: 11.01.2020.]

[6] *Prodaja guma za viljuškare*. Dostupno na: http://www.tigor-trade.rs/prodaja-guma-za-viljuskare/ [datum pristupa: 22.01.2020.]

[7] Gavanski D, Jelačić, I. 2019. *Analiza ispravnosti zvučne signalizacije viličara u Republici Srbiji*, Časopis Sigurnost 61 (3) 251-256, Zagreb, Republika Hrvatska: Zavod za istraživanje i razvoj sigurnosti d.d.

Dostupno na: https://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=329129 [datum pristupa: 22.01.2020.]

[8] *Forklift Safety Guide*. Dostupno na:

https://depts.washington.edu/wineryhs/Content/Forklift%20Safety%20Guide.pdf [datum pristupa: 22.01.2020.]

[9] *High Risk Work – A guide to forklift safety*. Dostupno na: https://www.safework.sa.gov.au/sites/default/files/forkliftsafety.pdf [datum pristupa: 22.01.2020.]

[10] Jovanović, M., Tomić, O. 2008. *Upotreba viljuškara u podsistemu unutrašnjeg transporta i skladištenja sa aspekta bezbednosti*, Objavljeno u: 3. srpski simpozijum sa međunarodnim učešćem Transport i logistika, str. 18.1-18.6, Niš, Republika Srbija: Univerzitet u Nišu. Mašinski fakultet. Katedra za transportnu tehniku i logistiku. Dostupno na: http://ttl.masfak.ni.ac.rs/til2008/Zbornik/Zbornik_radova_TIL2008.pdf [datum pristupa: 22.01.2020.]

AN ANALYSIS OF THE STATE OF WHEELS OF FORKLIFTS IN EXPLOITATION

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Abstract: The aim of this paper is to analyze the state of the wheeles on the forklifts wheels in exploatation. The methodology is presented that was used to analysis the state of forklifts wheels. The descriptive method based on a checklist was used.

The research was conducted on 127 forklifts of average age 15 years. It was determined that about 15% forklifts had the problem of using overly worn and / or mechanically damaged of wheeles . The results of the analysis are discussed and further courses of action are proposed.

Key words: *forklifts, wheeles, methodology, research, analysis, checklist.*

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INNOVATIVE SOLUTION IN THE MODELING OF FOOD DISTRIBUTION CHANNELS AS A FACTOR OF SUCCESSFUL ORGANIZATION OF AGRICULTURAL PRODUCTION

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Summary: Profit maximization in the agricultural sector should go in the direction that will enable agricultural products to be marketed through a realistic distribution channel. This applies in particular to the distribution channel of the food supply. In addition, the food distribution system should focus on the dominant observation of the production of food produced inland. Food distribution should take into account market competition, distribution and logistics costs, the existence of unequal quantities of food shipments, etc. That is why it is of great importance to adopt realistic models that will appreciate modern innovative ways of logistics that will help real food distribution. In addition, up-to-date information and communication technologies should be respected to support such distribution approaches. This paper draws attention to the importance of implementing a possible new food distribution model based on an innovative approach.

Key words: *short food supply chain; distribution; sustainability; information and communication technology; business process modelling*

INTRODUCTION

Buyers who are interested in modeling the food supply process should be consistent with maintaining the agricultural sustainability principle.

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This means that the principles of economic, environmental and social nature are respected while providing progressive opportunities to pursue the planned activities.

The basis of such modeling should be to satisfy the management of agriculture and the unmanageable food management, which will mean the practical management of the distribution channel, which will be in accordance with the planned economic plans of the drivers of activity.

Modeling regarding food management and its distribution should take into account the current economic conditions. The aim of the activity is to reduce the number of traffic participants, to reduce the brokerage fee, while facilitating the control of the selling price.

Such observation should be with respect for a sustainable society and impact on social development. Therefore, the distribution of agricultural products, respectively, of food observed in the management of [1], [2], [3], [4], [5] heterogeneous factors that affect the distribution of food [6], [7], [8] , [9], [10] which functionally occurs in the model of distribution of movement of movement [11], [12], [13], [14] of food towards the end consumer [15] which is viewed as the focus of economic activities.

MANAGING FOOD DISTRIBUTION AS A BASIS FOR MODELING DISTRIBUTION CHANNELS

Managing the distribution of food, viewed through the flow of food, from the place of production to the point of sale to customers, should be viewed through the justification of the total spend on the process of logistics activities.

Contemporary management that faces distribution channels in the context of contemporary logistics trends should primarily reduce costs. This is achieved through the use of digitization, which will facilitate communication with the end customer and strengthen all activities in the observed food distribution channel to the end user.

A factor that must be respected on a continuous basis is towards satisfying technological advances in the field of information and communication technologies. This requires an appreciation of the model in the process of implementing a logistical strategy in the agricultural business that is complemented by food production. It is essential to allow for rational, economically viable distribution of food within the territory of a country.

The food distribution thus observed is basically viewed in relation to the needs of customers who accept to pay at affordable prices for the food thus offered. The basis for this study is to find an effective food distribution model system, that is, an innovative approach to modeling food distribution channels.

INNOVATIVE LOGISTICS SOLUTIONS AS A PRODUCT OF THE SUPPLY CHAIN MANAGEMENT STRATEGY

When defining a supply chain management strategy, companies are confronted with a number of limiting factors that result from the changes that are happening in the global economic environment.

These changes, in the form of new trends, affect the business strategy, which directly depends on the choice of strategy to be applied by the companies dealing with the organization of food distribution in a particular market.

The authors illustrate possible solutions that will implement innovations in the logistics approach to food distribution through the illustrations in Figure 1.

Fig.1 Framework for defining SCM strategy generally

RESPECT FOR THE FOOD DISTRIBUTION CHANNEL ENVIRONMENT

The authors provide a possible overview that points to the observation and importance of the environment from the impact on the consumer as a target category, which is the focus of all movements in the form of tracking the product from the moment of creation to the moment when it is offered for sale. The authors illustrate the importance and the impact on the consumer of the environment by presenting the number 2 image.

This implies that the environment influences changes in business and competitive strategies, which is ultimately the result of changes in strategy that will be implemented by new and innovative logistics in the distribution of food in the country by companies primarily engaged in agricultural business.

Such a practical model of behavior requires the application of the following factors of influence on the customer as a key point of the distribution system. The view is given in Fig.2, a possible way to organize and influence the customer as a key category of observation.

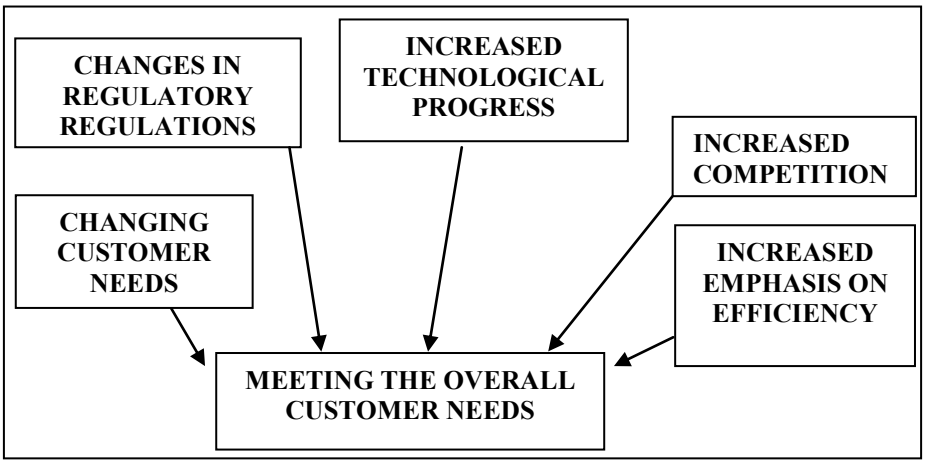

Fig. 2 Meeting the needs of customers who are the focus of interest for food distribution companies

DISCUSSIONS

The formation of innovative models of a sustainable efficient logistics system in food production that is complementary to agriculture is of great importance for the formation of a new logistics system for food distribution. It is essential for the development of a logistical food distribution system the introduction of innovative models that will empower distribution in the economy of a country.

In this paper, the authors have drawn attention to the existence of an innovative approach or model by which the implementation of the logistics distribution model in food distribution channels that are essentially produced by agriculture in one country will be implemented.

In this way, through the use of logistical capacities of food distribution, to meet the basic and desired needs of customers, they can be realized at decent and realistic prices that the buyers of products will be able to pay.

CONCLUSION

In this paper, the authors draw attention to the use of innovative models that are possible and applicable in the distribution of food in a country that meets the needs of customers at real economic prices.

The authors provided an example of an innovative possible model that can be upgraded and form the basis for future research in the process of forming a model of innovative food distribution.

This approach, that is, a model that will be able to incorporate some important innovations in food distribution and customer satisfaction, should be seen as an economically logical model. However, there are limitations in implementation. They relate to the required quantities of food produced in the country, the existence of relatively high costs, especially transport, trade costs, etc.

One way to solve the problem of distribution efficiency can be solved by forming a cluster of manufacturers to share their transportation resources and through a common distribution planning process. In addition to the advantages and disadvantages of the models presented by the authors in the work, the choice of a particular distribution model should also take into account the following factors: size of the food distribution lot, duration, range, risk of purchase error, transaction costs, support for service, customization, and many others factors that may be relevant to speed up the management of, above all, food distribution companies produced by the agrarian sector of the country. All this needs to be included and addressed in some future research.

REFERENCES

[1] Damodaran, A. (2007). Korporativne finansije: teorija i praksa, Podgorica, Modus.
[2] Cantino, V. (2009). Korporativno uptravjanje, merenje performansi i normativna usaglašenost sistema internih kontrola, Beograd, Data Status.
[3] Engelseth P. (2016). Developing exchange in short local foods supply chains. Int. J. Food System Dynamics, 7(3): 229-242.
[4] Stahlbrand L. (2016). Short food supply chains and "infrastructure of the middle": The role of university food procurement in sustainability transition. Wilfrid Laurier Univ., Waterloo, Canada.
[5] Martikainen A, Niemi P, Pekkanen P. (2014). Developing a service offering for a logistical service provider-case of local food supply chain. Int. J. Production Economics. 157: 318-326.
[6] Kull TJ, Chae S, Choi T. (2017). The Future of Supply Chain Management. S. Chain 24/7.
[7] Casadesus-Masanell R, Feng Z. (2013). Business model innovation and competitive imitation: the case of sponsor-based business models. Strategic Management Journal, 34(4): 464-482.
[8] Janssen GR, de Man AP, Quak HJ. (2015). Strategic business models for cross-chain control centers (4C). In: de Kok T, van Dalen J, van Hillegersberg J. (eds.) Cross-chain collaboration in the fast moving consumer goods supply chain. Eindhoven University of Technology, Eindhoven, Rotterdam, Enschede, Netherland.
[9] Thilakasiri T. (2010). Importance of business process reengineering.
[10] Ribeiro C, Fernandes J, Lourenco A, Borbinha J, Pereira J. (2012). Using serious games to teach business process modeling and simulation. In: Proceedings of the 2012 World Congress in Computer Science, Computer Eng., and Applied Computing, 16-19, Las Vegas, Nevada, USA.
[11] Verdouw CN, Beulens AJM, Trienekens JH, Wolfert S. (2010). Business process modelling in demand-driven agri-food supply chains. In: Proceedings in System Dynamics and Innovation in Food Network, 307-322.
[12] Engelseth P, Hogset H. (2016). Adapting supply chain management for local foods logistics. Int. J. Food System Dynamics, 7(3): 143-160.
[13] Northouse, P. (2008). Liderstvo. Beograd, : Data Status.
[14] Rodriguez, M., Miguel, Sanchez, L., Cejudo, E. & Antonio, C. (2019). Variety in local development strategies and employment: LEADER programme in Andalusia. Agric. Econ. – Czech, 65: 43-50.
[15] Nowak, A., Janulewicz, P., Krukowski, A. & Bujanowicz-Haraś, B. (2016). Diversification of the level of agricultural development in the member states of the European Union. Cahiers Agricultures, 25: 55004.

INOVATIVNO REŠENJE U MODELIRANJU KANALA DISTRIBUCIJE HRANE KAO FAKTOR USPEŠNOSTI ORGANIZACIJE POLJOPRIVREDNE PROIZVODNJE

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Sažetak: Maksimalan profit u poljoprivrednom sektoru treba da ide u pravcu koji će omogućiti da produkti poljoprivredne delatnosti mogu da se plasiraju na tržištu putem realanog kanala distribucije.

To se naročito odnosi na kanal distribucije snabdevanja hranom. Osim toga, sistem distribucije hrane treba da bude usmeren na dominatno posmatranje proizvodnje hranu koja se proizvodi unatar zemlje. Distribucija hrane treba da uvaži tržišnu konkurenciju, troškove distribucije i logistike, postojanje nejednakih količina pošiljki hrane itd. Zato je od velike važnosti da se usvoje realni modeli koji će uvažavati savremene inovativne načine logistike koji će pomoći realnu distribuciju hrane. Osim toga potrebno je i uvažavati savremene informacione i komunikacione tehnologije, kao potpore takvim pristupima distribucije.

Ovaj rad, skreće pažnju na značaj primene mogućeg novog modela distribucije hrane koji se zasniva na inovativnom pristupu.

***Ključne reči**: kratak lanac snabdevanja hranom; distribucija; održivost; informaciono-komunikaciona tehnologija; modeliranje poslovnih procesa*

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PRIMENA ANALIZE SLIKE ZA ODREĐIVANJE DIMENZIJA SEMENA ULJANE REPICE KORIŠĆENJEM IOT KONCEPTA

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Sažetak: U radu su analizirane geometrijske karakteristike semena, ujednačenost i površina poprečnog preseka semena uljane repice na osnovu koje je izračunat ekvivalentni prečnik. Poznavanje dimenzije semena je od značaja u semenskoj proizvodnji od setve, žetve, dorade, skladištenja do pakovanja semena. Utvrđivanje dimenzije semenki ručnom metodom je dosta spor proces tako da je cilj ovog rada bio prikaz jednog računarski podržanog uređaja koji sadrži kameru i može da fotografiše uzorke semena, a pri tome i da utvrdi dimenzije semenki programskom analizom slike. Predstavljeni uređaj je realizovan u skladu sa konceptom Interneta stvari (IoT) tako da ima mogućnost povezivanja na Internet i prosleđivanja slike, ili u drugoj varijanti može izvršiti direktno analizu slike i dalje da prosledi samo rezultate. Namena predstavljenog sistema za utvrđivanje veličine semena jeste da na brz i efikasan način korisnici dobiju prve rezultate koji će im pomoći u realizaciji daljih aktivnosti koji se tiču rada sa sitnim semenom.

Ključne reči: *analiza slike, seme uljane repice, IoT (Internet of Things), Raspberry Pi 3*

UVOD

Prikupljanje i obrada senzorskih podataka poslednjih godina omogućila je dosta prostora za efikasnije sprovođenja radnih aktivnosti. Sistemi zasnovani na procesuiranju senzorskih podataka mogu predstavljati značajnu pomoć ljudima u izvođenju radnih

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procesa na optimalan način, uz praćenje stanja i aktivnosti na osnovu kojih se mogu donositi zaključci koji dalje mogu unaprediti rezultate rada.
Prikupljanje senzorskih podataka je dosta olakšano primenom sistema sa bežičnim senzorskim mrežama dok je u poslednje vreme istaknut novi koncept poznat kao internet stvari ili IoT (Internet of Things). Na taj način, osim ljudima i računarski podržanim objektima (stvarima) je omogućeno povezivanje na Internet i razmena podataka preko mreže. Podaci dobijeni od strane senzora mogu se prenositi do udaljenih servera na Internetu, odnosno do Cloud platformi, gde podaci mogu biti lako dostupni za prikazivanje ili dalju obradu. Mogu se koristiti raznovrsni senzori za prikupljanje podataka, a među njih mogu se svrstati i kamere koje imaju posebno široku primenu kao posebni uređaji ili dodatni moduli pružajući sliku trenutnog stanja sa nadziranog mesta. Aplikacije koje se zasnivaju na analizi slike mogu biti od velike pomoći u oblasti poljoprivrede tako što se na osnovu otkrivenih karakteristika na slici, dobijenih automatskom analizom, mogu generisati nove informacije. Značaj i prednosti primene ovih aplikacija mogu se pronaći u istraživačkim radovima u domenu poljoprivrede, kao što su primeri: klasifikator paradajza na osnovu boje, veličine i težine [1], utvrđivanje površine i zapremine asimetričnih poljoprivrednih proizvoda [2], automatska identifikacija vizuelnih efekata koji ukazuju na bolesti biljaka [3], segmentacija relevantnih tekstura na slikama kao što je identifikacija biljaka i zemljišta [4] ili prepoznavanje useva i korova na osnovu analize slike u realnom vremenu [5].

Jedna od primera gde se može primeniti analizu slike je kod semena malih dimenzija tako da ih je teže ručno izmeriti za kratko vreme kao što je nadgledanje klijavosti semena koja pripadaju familiji kupusnjača (*Brassica*) [6]. U tu grupu sitnih semena spada seme uljane repice čije utvrđivanje karakteristika odnosno dimenzija predstavlja pokazni primer u ovom radu.

Ocena kvaliteta semenskog materijala je osnova za njegovu upotrebu, a vrši se na osnovu poznavanja fizičkih osobina semena svake partije. Dimenzije (veličina, krupnoća) i oblik su fizičke osobine neophodne da bi se seme opisalo. Semena poljoprivrednih kultura-biljaka imaju različite oblike i krupnoću. Vrednosti veličine-krupnoće semena i oblika se menjaju u zavisnosti od naslednih osobina sorti, agrotehničkih i agroekoloških uslova gajenja. Seme uljane repice ima loptasti oblik, tako da je u doradi semena vrlo lako i jednostavno izvršiti postupkom separacije-klasiranje semena po krupnoći pomoću rupa-otvora na sitima različitih dimenzija.

Tačno određivanje (merenje) dimenzija sitnih semena pomoću šublera je mukotrpan, vrlo spor i dugotrajan postupak. Zbog toga je postojala potreba da se pronađe drugačiji metod za lako i brzo utvrđivanje dimenzija svih semena, a posebno sitnih semena. I upravo zbog toga, cilj ovih istraživanja je da se predstavi jednostavan, brz i nedestruktivan metod za merenje dimenzija semena, posebno sitnog, korišćenjem digitalne obrade slike. Cilj ovog rada je prikaz IoT zasnovanog sistema koji bi mogao uslikati upravo seme uljane repice i sliku proslediti na Cloud platformu za dalju analizu ili u drugoj varijanti slika bi mogla biti analizirana blizu mesta merenja što bi odgovaralo konceptu Fog računarstva. Na taj način određeni nivo obrade bi mogao biti prenet sa Interneta na uređaj bliži mestu merenja pri čemu se izbegava prenos većeg obima podataka.

MATERIJAL I METODE RADA

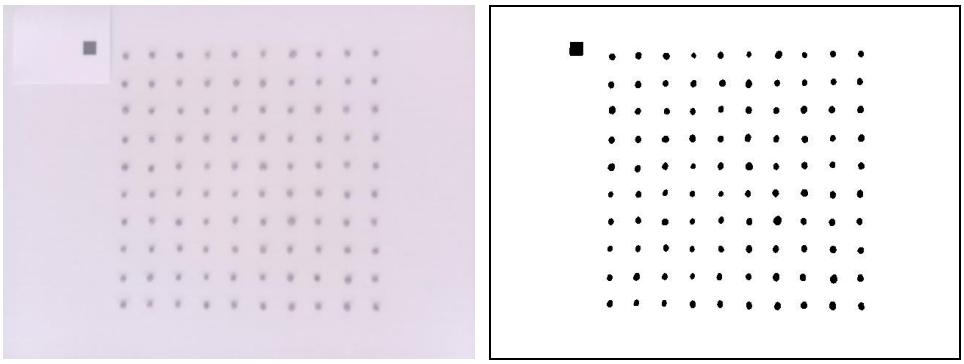
Za merenje dimenzija semena uljane repice korišćeno je neoštećeno, suvo, čisto seme bez prisustva stranih primesa sorti „Slavica", „Jasna" i „Banaćanka".

Za potrebe eksperimenta implementirana je aplikacija za analizu slike zasnovana na IoT sistemu koji je realizovan sa Raspberry Pi 3 računarskom modulu sa priključenom odgovarajućom RPi kamerom. Pored mogućnosti prosleđivanja slike na Cloud platformu u ovoj varijanti analiza slike je vršena upravo na uređaju na mestu gde se vrši merenje.

Raspberry Pi predstavlja računar koji karakterišu male dimenzije, značajna procesorska snaga, relativno niska cena i to sve na jednoj ploči (modulu) koji se na tržištu pojavio 2012. godine. Takođe sadrži više raznovrsnih interfejsa koji mu pružaju široke mogućnosti u povezivanju i interakciji sa drugim uređajima. Uz dodatak odgovarajućih perifernih jedinica može se koristiti kao standardni personalni računar, a sa omogućenim povezivanjem na Internet može biti korišćen kao nezavisan uređaj sa udaljenim pristupom od strane korisnika. Na mestu memorijskog diska koristi SD karticu, dok se kao operativni sistem može koristiti Raspberry Pi OS poznat pod nazivom Raspbian jedan od posebno konfigurisanih Linux operativnih sistema [7].

Raspberry Pi 3 predstavlja treću generaciju Raspberry Pi računara koji su realizovani u potpunosti na jednoj ploči. Raspberry Pi 3 model sadrži 64-bitni četvorojezgarni mikroprocesor, radnu memoriju od 1 GB, komunikaciju sa bežičnom mrežom (Wireless) i Bluetooth 4.1, HDMI interfejs, četiri USB porta, slot za micro SD karticu, četrdeset pinova opšte namene, interfejs za kameru i kompozitni audio/video priključak [8]. Sa ovim modelom korišćena je Raspberry Pi kamera modul koja je zasnovana na Sony IMX219 senzoru.

Kućište uređaja koje sadrži Raspberry Pi 3 i odgovarajuću RPi kameru postavljeno je na nosaču i može se ručno pomerati po vertikalnoj osi (gore-dole). Ispod kamere na postolju, donjem delu nosača, postavljena je kutija sa semenom. Zbog bolje preglednosti na podlozi se nalaze otvori za semenke pri čemu je formiran šablon od deset vrsta i deset kolona, pri čemu u svakom može da se umetne po jedna semenka, što znači da se u jednom posmatra uzorak do 100 semenki (Sl. 1). Određena količina semena, odabrana slučajnim uzorkom iz džaka, sipa se u kutiju sa otvorima i vrši njihov razmeštaj u postojeće otvore tako da se svaki otvor na kutiji popunjava sa pojedinačnom semenkom. Na kraju se višak semena odstrani sa podloge tako da za snimanje ostane 100 semenki.



Slika 1. Postavka 10 x 10 semenki

Figure 1. Layout of 10 x 10 seeds

Ceo postupak se zasniva na postavci semena na beloj podlozi uz postavku i referentnog objekata poznatih dimenzija koji je poslužio kao reper prilikom određivanja površina poprečnog preseka semenki, odnosno ekvivalentnog dijametra. Poznati objekat predstavlja kvadrat dimenzija 5 x 5 mm.

Na prvom mestu postavlja se referentni objekat na osnovu koga se računaju dimenzije ostalih objekata (Sl. 1). Pošto semenke nisu savršeno sfernog oblika, da bi se izvršilo uzorkovanje na efikasan način postojećim sistemom izvršene su određene aproksimacije. Semenke su postavljene tako da se posmatra površina njihovog poprečnog preseka i usvaja se da je to površina kruga na osnovu koga se računa aproksimativni, odnosno ekvivalentni prečnik semenke prema obrascu (1):

$$R_p = \sqrt{\frac{4 \cdot P_p}{\pi}} \tag{1}$$

pri čemu je P_p površina poprečnog preseka semenke dobijena kao površina konture u pikselima, a R_p prečnik semenke takođe izražen u pikselima.

Na osnovu referentnog objekta računa se vrednost koeficijenata K_p koji se koristi za pretvaranje vrednosti ekvivalentnog prečnika u milimetre (2):

$$R_m = K_p \cdot R_p \tag{2}$$

pri čemu je R_m upravo vrednost prečnika pojedinih semenki u milimetrima.

Programski deo zadužen za analizu slike realizovan je u programskom jeziku Python. Nakon učitavanja slike programski se vrši pronalaženje kontura na slici shodno tamnijoj boji semena u odnosu na belu podlogu. Svaka od pronađenih kontura predstavlja po jedno seme, pri čemu se svaka od njih obeležava brojevima od 1 do 100 i za svaku se dobija površina poprečnog preseka, a odatle shodno obrascu (1) dobija se vrednost ekvivalentnog prečnika. Na osnovu dobijenih vrednosti za dijametre semena može se utvrditi ujednačenost krupnoće semena, odnosno koji udeo od posmatranog semena ima određenu krupnoću.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Poznavanje fizičkih karakteristika semena je značajno u svim fazama proizvodnje od setve, žetve, dorade semena, čuvanja i pakovanja. U postupku dorade semena obavljaju se određene tehnološke operacije koje uključuju pored ostalog prečišćavanje semena i klasiranje po krupnoći. Najvažnije osobine klasiranja semena su: debljina, širina, dužina, struktura površine, poroznost, elastičnost i boja. Pored ovih osobina za doradu plodova loptastog oblika, kao što je seme uljane repice, bitan je i ekvivalentni prečnik semena. Na osnovu maksimalnog prečnika semena određuju se veličine otvora sita koja će se koristiti u toku dorade semena uljane repice.

Veličina i ujednačenost semena je važna za setvu, jer od nje zavisi norma setve odnosno količina semena potrebna po hektaru i dubina setve.

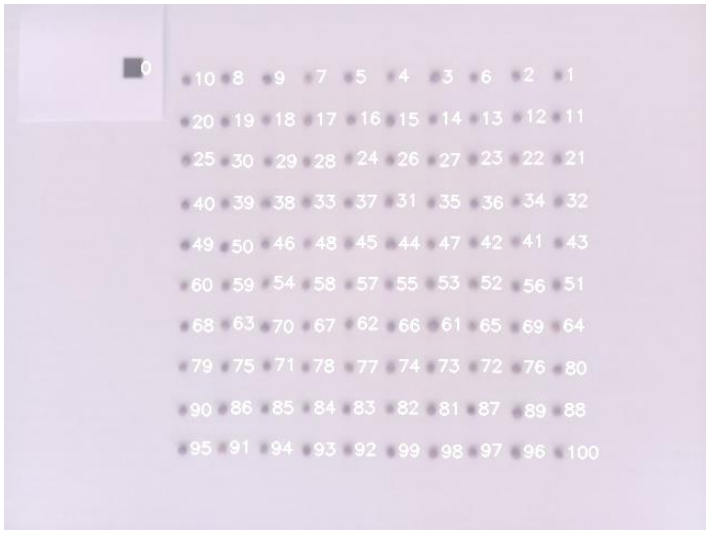
Veličina i oblik semena su bitni za konstrukciju mašina i opreme za odvajanje i klasiranje semena, kao i za predviđanje parametara u procesu sušenja [9], [10] i [11].

Pošto su u jednoj partiji semena različite krupnoće, moguće je, pri doradi semena za dobijanje različitih frakcija semena, u praksi postaviti dva sita različitih prečnika (minimalnog i maksimalno izmerenog prečnika semena).

Pored toga, poznavanje prečnika semena je važno i kod pripreme žitnih kombajna Zmaj 131, 132, 133, 134, 135 za žetvu uljane repice, pri čemu se podešava gornje sito i postavlja donje sito za uljanu repicu sa otvorima prečnika 2,5 mm. Krupnoća semena je važna osobina sa aspekta setve, sušenja, dorade i skladištenja semena uljane repice. Ujednačena veličina semena obezbeđuje kvalitetniji rad setvenog aparata i ravnomerniju dubinu setve. Krupno, dobro razvijeno seme poseduje veću količinu hranljivih materija što je garancija boljem nicanju i početnom razvoju mladih biljaka. Krupnije seme se sporije suši, zahteva veći prečnik sita i jaču vazdušnu struju.

Mehaničko odvajanje semena po frakcijama u laboratoriji sa sitima nije bilo dovoljno efikasno, jer su se frakcije razlikovale u veličini, pri čemu je svaka frakcija sadržala određeni broj semenki koje se preklapaju sa drugim frakcijama. Pristup prikazan u ovom radu predstavlja primenu analize slike u određivanju ekvivalentnog prečnika svake pojedinačne semenke.

Obrada, odnosno analiza slike je jednostavna, brza i neinvanzivna metoda u merenju ekvivalentnog prečnika, površine i zapremine semena [12]. Digitalna analiza slike može se koristiti pored utvrđivanja procene kvaliteta uljane repice, uključujući određivanje geometrijskih karakteristika, boje, površine semena, takođe i za identifikaciju nečistoće koju je teško odvojiti u procesu čišćenja [13] i za brojanje semenki [12] ili praćenje klijanja semena. Prikaz jednog takvog sistema koji može da vrši uzorkovanje putem slike sa mesta merenja predstavljen je u radu [8].



Slika 2. Numerisane semenke za koje se računa ekvivalentni dijametar

Figure 2. Marked seeds by numbers for which the equivalent diameter was calculated

Informacije o fizičkim i mehaničkim osobinama ratarskih useva su od suštinskog značaja za selekciju pri stvaranju novih sorti. U toku oplemenjivanja pri stvaranju novih sorti potrebno je kod velikog broja ljuski različitih linija utvrditi broj semena i za dalju selekciju odabrati linije sa većim brojem semena u ljuski.

U laboratorijama se dimenzije svakog semena iz ljuske uljane repice sa jedne biljke utvrđivao ručnim merenjem pomoću šublera što zahteva mnogo vremena.

Prednost merenja dimenzija na bazi programske analize slike je u tome što je skraćen postupak i vreme trajanja za utvrđivanje dimenzije semena. Sva zrna sipaju se u posudu na čijoj se podlozi nalaze otvori manji od minimalnog prečnika semena uljane repice. Protresanjem posude semena samo delimično upadaju u otvore, pri čemu se ne vodi računa o njihovom položaju i mestu u njoj. Posuda se postavi ispod IoT uređaja koji sadrži kameru, pri čemu se za svega nekoliko sekundi uslikaju semena, odredi broj zrna, površinu poprečnog preseka, na osnovu toga i ekvivalentni prečnik, kao i ujednačenost po veličini semena uljane repice. Na ovaj način olakšan je mukotrpan posao ljudi u laboratorijama koji se odnosi na ručno merenje svake semenke. Umesto toga na ovaj način se za vrlo kratko vreme određuju dimenzije semena i uštedi se vreme što je važno pri merenju velikog broja uzoraka.

Ispitivanja semena su obavljena u tri ponavljanja za sve tri sorte. Svako seme je pojedinačno obeleženo (numerisano) i utvrđene su mu navedene veličine (Sl. 2) .

U toku snimanja dobijaju se osnovni statistički podaci o ekvivalentnim dijametrima kod posmatranih uzoraka semena, kao što su aritmetička srednja vrednost, minimalna i maksimalna vrednost, medijana i standardna devijacija (Tab. 1).

Tabela 1. Izračunati podaci za vrednosti prečnika posmatranih uzoraka semena

Table 1. Calculated values of diameter for the observed seed samples

Dijametar *Diameter*	„Slavica”	„Jasna”	„Banaćanka”
Srednja vrednost *Average value*	*2,11*	*2,22*	*2,30*
Minimum *Minimum*	*1,46*	*1,57*	*1,70*
Maksimum *Maximum*	*2,84*	*2,69*	*3,14*
Medijana *Median*	*2,10*	*2,25*	*2,32*
Standardna devijacija *Standard deviation*	*0,240*	*0,240*	*0,243*

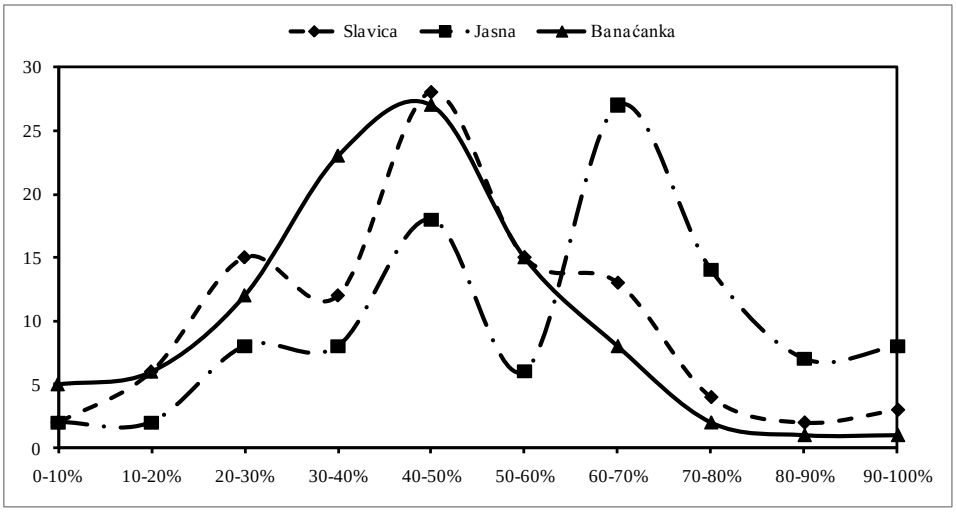
Na osnovu Tab. 1 vidi se da su aritmetičke srednje vrednosti izračunatih ekvivalentnih prečnika približno iste za posmatrane uzorke sve tri sorte, pri čemu se može uočiti da u trenutno posmatranim uzorcima sorta „Banaćanka” ima za nijansu krupnije seme. Na osnovu vrednosti za medijanu može se videti da je raspodela krupnoće semena podjednaka u odnosu na opseg od minimalne do maksimalne vrednosti. Ako bi se posmatrao taj opseg i podelio na deset delova, raspodela semenki po krupnoći bi bila kao u Tab. 2 Može se uočiti da se najveći broj semenki nalazi u delu od 40-50% od opsega krupnoće za sorte „Slavica” i „Banaćanka”, dok za sortu „Jasna” najveći broj semenki nalazi se u delu 60-70% od njenog opsega krupnoće.

Tabela 2. Raspodela semenki po krupnoći na posmatranom uzorku od 100 semenki

Table 2. Seed size distribution on the observed sample of 100 seeds

Opseg krupnoće semena *Seed size range*	„Slavica"	„Jasna"	„Banaćanka"
0-10%	*2*	*2*	*5*
10-20%	*6*	*2*	*6*
20-30%	*15*	*8*	*12*
30-40%	*12*	*8*	*23*
40-50%	*28*	*18*	*27*
50-60%	*15*	*6*	*15*
60-70%	*13*	*27*	*8*
70-80%	*4*	*14*	*2*
80-90%	*2*	*7*	*1*
90-100%	*3*	*8*	*1*

Upravo vrednosti broja semenki razvrstani po krupnoći predstavljeni su na Graf. 1 i može se uočiti njihova raspodela na celom opsegu od minimalne do maksimalne vrednosti koja je izdeljena na deset delova. Pikovi na grafikonu ukazuju za koju krupnoću semena se nalazi najveći broj semenki na posmatranom uzorku.



Grafik 1. Prikaz raspodele broja semenki po krupnoći

Chart 1. Displayed distribution of the number of seeds by size

Celokupan prikaz dobijenih vrednosti za uzorke navedene tri sorte poslužio je kao pokazni primer. Akcenat je na mogućnosti primene jednog ovakvog uređaja, zasnovanog na konceptu Interneta stvari (IoT), na novim uzorcima tako da se na jedan dovoljno brz i efikasan način može uslikati seme i dobiti rezultati. U ovoj fazi nije bio fokus na detaljnim analizama svih fizičkih karakteristika semena već da se pomoću kamera modula i koncepta prenosa i analiza slike mogu dobiti prvi rezultati koji će pružiti pomoć u pravcu sprovođenja drugih aktivnosti pripreme i dorade semena.

ZAKLJUČAK

Digitalna analiza slike je korisna metoda za brzu obradu velikog broja uzoraka semena pri utvrđivanju veličine i ujednačenosti semena jedne partije. Oprema i softver potrebni za digitalnu analizu slike su relativno jeftini, a postupak jednostavan i brz, tako da veliki broj uzoraka može biti obrađen u jednom danu. Projektovanim uređajem moguće je odrediti dimenzije preko proračuna ekvivalentnog prečnika analizom slike. Sledeća faza bi podrazumevala dodavanje aparature uz pomoć koje bi se na isti način mogla uslikati semena sa većom rezolucijom kako bi se dobile i ostale fizičke osobine (srednji geometrijski prečnik, aritmetički prečnik, zapremine, površina, sferičnost, zaobljenost, boja i drugo).

LITERATURA

[1] Clement, J., Novas, N., Gazquez, J.A., Manzano-Agugliaro, F. 2012. High speed intelligent classifier of tomatoes by colour, size and weight. *Spanish Journal of Agricultural Research*. 10 (2): 314-325.

[2] Sabliov, C.M., Boldor, D., Keener, K.M., Farkas B.E. 2002. IMAGE PROCESSING METHOD TO DETERMINE SURFACE AREA AND VOLUME OF AXI-SYMMETRIC AGRICULTURAL PRODUCTS. *International Journal of Food Properties*. 5 (3): 641-653.

[3] Camargo, A., Smith, J.S. 2009. An image-processing based algorithm to automatically identify plant disease visual symptoms. *Biosystems Engineering*. 102 (1): 9-21.

[4] Guijarro, M., Pajares, G., Riomoros, I., Herrera, P.J., Burgos-Artizzu, X.P., Ribeiro, A. 2011. Automatic segmentation of relevant textures in agricultural images. *Computers and Electronics in Agriculture*. 75 (1): 75-83.

[5] Burgos-Artizzu, X.P., Ribeiro, A., Guijarro, M., Pajares, G. 2011. Real-time image processing for crop/weed discrimination in maize fields. *Computers and Electronics in Agriculture*. 75 (2): 337-346.

[6] Dell' Aquila, A. 2009. Digital imaging information technology applied to seed germination testing. A review. *Agronomy for Sustainable Development*. 29: 213-221.

[7] Vujović, V., Maksimović, M. 2014. Raspberry Pi as a Wireless Sensor Node: Performances and Constraints. Objavljeno u: *2014 37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, pp. 1247-1252. Opatija, Hrvatska.

[8] Pagnutti, M.A., Ryan, R.E., Cazenavette, G.J., Gold, M.J., Harlan, R., Leggett, E., Pagnutti, J.F. 2017. Laying the foundation to use Raspberry Pi 3 V2 camera module imagery for scientific and engineering purposes. *Journal of Electronic Imaging*. 26 (1) 013014: 1-13.

[9] Koprivica, R., Turan, J., Veljković, B., Radivojević, D, Bokan, N., Đurović, D., Đokić, D., Balalić, I. 2018. Physical properties of oil rapeseed kernels at different moisture content and varieties. Objavljeno u: Proceedings 46th International Symposium: Actual tasks on agricultural engineering ATAE, pp.397-405, Opatija, Croatia.

[10] Đokić, D., Stanisavljević, R., Terzić, D., Marković, J., Radivojević, G., Anđelković, B., Barać, S. 2012. Primena različitih tehnoloških procesa u doradi semena crvene deteline. *Poljoprivredna tehnika*, 3: 1-10.

[11] Babić, M., Babić, Lj. 2007. Fizičke osobine poljoprivrednih materijala. *Autorizovana predavanja*. Poljoprivredni fakultet, NoviSad.

[12] Firatligil-Durmuş, E., Šárka, E., Bubník, Z. 2008. Image vision technology for the characterisation of shape and geometrical properties of two varieties of lentil grown in Turkey. *Czech Journal of Food Sciences*, 26:109-116.

[13] Tanska, M., Rotkiewicz, D., Kozirok, W., Konopka, I. 2005. Measurement of the geometrical features and surface color of rapeseeds using digital image analysis. *Food Research International*, 38 (7): 741-750.

APPLICATION OF IMAGE ANALYSIS FOR DETERMINATION OF RAPESEED DIMENSIONS USING IOT CONCEPT

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Abstract: The paper analyzes the geometric characteristics of seeds, uniformity and cross - sectional area of rapeseed, on the basis of which the equivalent diameter was calculated. Knowing the dimensions of seeds is important in seed production from sowing, harvesting, processing, and storage, to seed packaging. Manual determination of the dimensions of seeds is a rather slow process, so the aim of this work was to show a computer-aided device that contains a camera and can take seed samples, while determining the dimensions of seeds by program image analysis. Presented device is realized in accordance with the concept of the Internet of Things (IoT) so it has the ability to connect to the Internet and forward the image, or in another variant can directly perform the image analysis and further forward the results only. The purpose of the presented system for determining the size of seeds is providing a fast and efficient way for users to get the first results that will help them in the implementation of further activities related to working with small seeds.

Key words: *image analysis, rapeseed, IoT (Internet of Things), Raspberry Pi 3*

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DEVELOPMENT OF A SINGLE SCREW EXTRUDER FOR THE PRODUCTION OF WOOD-PLASTIC COMPOSITE

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Abstract: This study was carried out to design, fabricate, assemble and evaluate the performance of a laboratory scale wood-plastic composite (WPC) single screw extruder that can be used for recycling wood and plastic waste materials using locally sourced materials based on availability, strength and cost effectiveness. The extruder is separated into four units; the feeding, conveying, heating and forming unit. The designed parts were; the hopper capacity, the shaft diameter, the screw dimensions (pitch, helix angle and diameter), and the capacity on the conveyor (feed throats, compression and metering units) units. The developed machine was evaluated by using it in extruding low density plastic wastes and gmelina (*Gmelina arborea)* sawdust. The results showed a hopper capacity of 38.3m^3, shaft diameter of 60mm, screw dimensions (diameter=20mm, pitch=50mm, and helix angle = 17.65^0). The performance evaluation of the machine indicated an efficiency of 85% for the machine at an operating speed of 268rpm (4.5rps) with a throughput of 17.55kg/hr during a maximum period of 5 minutes. The mean water absorption (0.45-13.68%) and thickness swelling (0.14 – 0.94%) observed for the composites produced compared favorably with those reported in literature for WPCs recommended for non-structural indoor application purposes. The wood contents and soaking period had effects on the sorption properties and not the effectiveness or ineffectiveness of the machine. The machine conserves cost and energy due to low specific mechanical energy consumption of 191.21kJ/kg.

Key words*: Wood-Plastic Composite, Single Screw Extruder, Renewable Materials, Efficiency, Capacity, Specific Mechanical Energy*

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INTRODUCTION

Industrial logging and exploitation of the world's primary forest are rapidly destroying the habitats of animal and plant species which in turn lead to the depletion of the earth's ozone layer [1]. The destructive exploitation of hardwoods is also responsible for this widespread deforestation.

Wood based-industries generate sawdust from sanding, cutting, drilling and milling operations where wood is removed from a finished product. Wood dusts are very fine particles that are generated during sanding or other machining operations; it is often collected in filter bags or dust collectors and the activities of Plastics Manufacturers such as manufacturing, processing, transportation and consumption add stress to the environmental system by accumulating stock of waste [2, 3]. Today, polythene (and polypropylene), a polymer has been put to different use as containers, wrappers, sachets, bags and packages. Its extensive use has resulted in its litter in every nook and cranny of our roads, markets and other non-designated places. This has caused negative impacts on our environment as they are non-biodegradable.

More than thirty years ago, there has been an increasing concern in wood polymer composites and its applications have been growing and expanding. Environmental issues and high demands on lower material costs are the driving forces behind the increasing need of renewable materials. The accumulation of un-managed wastes especially in developing countries has resulted in an increasing environmental concern.

In Nigeria, recycling is highly necessary so as to reduce the volume of waste generated and also to serve as a means to solving environmental degradation problems as these wastes are currently disposed in sanitary landfills or openly dumped into uncontrolled waste pits and open areas. The Environmentalists including the Engineers have been challenged to develop technically reasonable solutions to environmental waste problems.

Wood-plastic composites (WPC) are made up of two main constituents, though both are polymer based, they are very different in structure, performance as well as origin. Polymers are high molecular weight materials whose performance is largely determined by its molecular composition. In WPCs, the polymer matrix forms the continuous phase surrounding the wood component. These polymers are typically low cost commodity polymers which flow easily when heated and allowing considerable processing flexibility when wood is combined with them. Thus due to the low thermal stability of wood, only polymers with processing temperatures lower than 200^{o}C can be used in WPC. These polymers tend to shrink and swell with temperature but absorb little moisture and can be effective barriers to moisture intrusion in a well-designed composite. The most common polymers used are polyethylene (PE), polypropylene (PP) and polyvinylchloride (PVC).

As a result, the objective of this work was to design and construct a single screw extruder machine that can be used to produce Wood-Plastic Composites from wood wastes and plastic that litters and to evaluate the performance of the machine.

Extruder Description

The extruder is an assembly of a screw-shaft system being rotated by a medium speed electric motor. The screw is housed in a heated cylindrical barrel that employs two processing stages, melting and metering, and a vent section to remove volatiles. The material is fed through a gravity hopper. The melting/mixing mechanism is through barrel heating and screw shearing while the extrudate is metered through the breaker plate and die which gives the product its profile. The output rate is directly related to the screw speed: an increase in screw speed will result in an increased throughput. A pulley and v-belt system is attached to an electric motor to control the screw speed which in turn controls the output rate.

MATERIAL AND METHODS

The materials used for the project work were locally sort machine parts for the fabrication of the Single Screw Extruder, and waste water sachets, plastic bottles and sawdust for the performance evaluation.

Design of the Single Screw Extruder

The design of the Single Screw Extruder was adapted from engineering design principles found in literatures and textbooks [4 – 10].

Design Parameters

In order to achieve the set objectives, the extruder is separated into five units i.e. the feeding, conveying, heating, power unit and forming unit as shown in the exploded view of the extruder in fig. 1. Each of this unit performs specific functions.

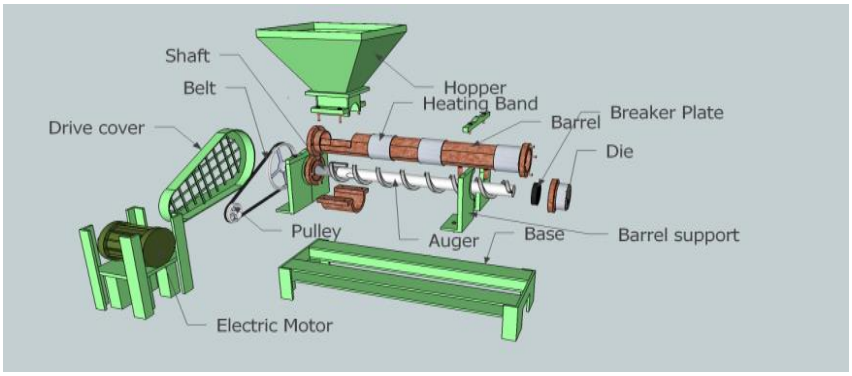


Fig. 1: Exploded view of the Extruder

***Feeding Unit*:** This unit is made up of the hopper, where the materials for processing are fed into the machine and are transported from the top, (inlet), down through the feed throat of the extruder.

The material mixture meets the auger at the feed throat. There are vertical and horizontal forces present in the hopper and act on the inside wall of the hopper.

Therefore, since the operation will be done in batches, the size selected should be considerably small to increase efficiency and also large enough to ensure high production rate.

***Conveying Unit*:** This unit is made up of the screw conveyor also known as the auger. It conveys the mixture that are fed down from the hopper through the feed throat down to the die, with the help of the electric motor, belt and shaft system, passing them through various heating zones. The screw has a pitch of 50mm i.e. the material moves a distance of 50mm in a revolution. The screw also enables mixing required during the process and to generate a stable and homogenous supply of the mixture to the die.

Heating Unit: The heating unit is made of four heating bands wrapped round the body of the barrel and connected to a power source. The heater provides heat to melt the plastic and is set at 180^{o}C to avoid burning the wood content which undergoes thermal degradation at 220^{o}C.

***Power Unit*:** This unit is made up of the electric motor (2hp), V-belt and pulley and the shaft.

Forming Unit: This unit is made up of; the screen pack, the breaker plate, and the die. At this section, the mixture is already in molten form and flows through the screen pack where it is screened to remove impurities and then to the breaker plate which helps to increase the back pressure for proper mixing of the molten and finally to the die which is attached to the extruder through an adapter changing the direction of flow where it takes the final shape.

Design Requirements

The considerations made in the design of the single-screw extruder to enhance effectiveness, safety and affordability include that the power requirement should be minimal, the component should be easy to dismantle, assemble and easily replaced in case of any damage or failure, and the design size will be small-scaled for easy construction at minimum cost and simplicity without compromising standards. The materials of construction used were locally sourced and dependent on suitability, availability, cost effectiveness and strength.

Design Analysis

Assumptions, established theories, principles and engineering equations were used to evaluate the necessary design parameters, strength and size of materials for consideration in the selection of the various machine parts so as to mitigate failure during working span of the machine.

Design of Hopper: The maximum volume of the composite material that the machine can handle in one operation is calculated thus from equation (1).

The top diameter is taken as 3 times the lower diameter [7],

$$V = \frac{1}{3}\pi R^2(H+h) - \frac{1}{3}\pi r^2 H \quad (1)$$

From Frustum law,

D = 45cm = 0.45m, d = 15cm = 0.15m, h = 50cm = 0.5m

$$\frac{H}{r} = \frac{h+H}{R} = \frac{H}{0.075} = \frac{0.5+H}{0.225}$$

H = 0.25m

$$V = \left[\left(\frac{\pi \times 0.225^2}{3} \times (0.25+0.5)\right) - \left(\frac{\pi \times 0.075^2 \times 0.25}{3}\right)\right] = 0.0383m^3 \text{ or } 38.3litres$$

But, volume of hopper = volume of polymer + volume of wood content

Volume of polymer (60% of total volume) = $\frac{60}{100}$ x $0.0383 = 0.023m^3$

Volume of wood content (40% of total volume) = $\frac{40}{100}$ x $0.0383 = 0.015m^3$

The mass and weight, of the polymer and wood content to be fed into the hopper, were determined using equation (2) and (3) respectively;

Mass (M) = Density (ρ) X Volume (V) (2)

W = M x g (g= acceleration due to gravity (3)

For plastic, $M_p = 530.8kg/m^3 \times 0.023m^3 = 12.2kg$

W_p = 12.2 x 9.81 = 119.68N (W_p = weight of plastic)

For wood, $M_w = 112\ kg/m^3 \times 0.015m^3 = 1.68kg$

$W_w = 1.68 \times 9.81 = 16.48N$ (W_w = weight of wood)

Weight of composite = 119.68N + 16.48N = 136.16N

Selection of Electric Motor: An electric motor of the following specification was selected;

Power = 2hp (1.49kw)

Rotational speed = 268rpm

Design of Pulley: In order to achieve the desired speed of the auger, variation of pulley is calculated using the equation (4) of speed ratio reported by Nwaigwe, *et al.* [8],

$$\frac{D_r}{D_m} = \frac{N_m}{N_r} \quad (4)$$

Where; N_m = rotational speed of electric motor (268rpm) [7].

N_r = rotational speed of rotor

D_r = diameter of rotor pulley (driven pulley, 400mm)

D_m = diameter of motor pulley (driver pulley, 75mm)

$$N_r = \frac{D_m \times N_m}{D_r} = \frac{75\ X\ 268}{400} = 50.25rpm$$

Design of the Belt Drive: Pitch line velocity of the belt was derived from equation (5) given by Khurmi and Gupta, [5];

$$V = \frac{\pi DN}{60} \quad (5)$$

Where,

D = Diameter of driver (75mm)

N = Revolutions per minute of the driver (268rpm)

Velocity of the belt, V was calculated thus;

$V = \frac{\pi \times 0.075 \times 268}{60} = 1.05m/s$

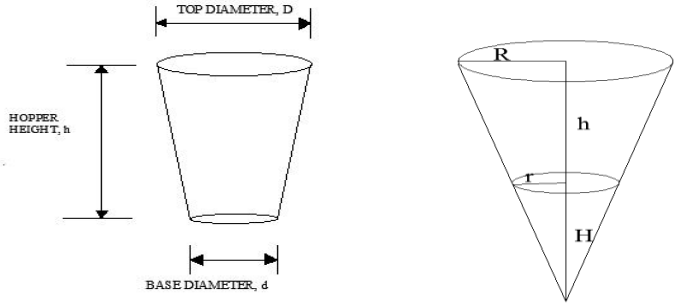
The type of drive belt used was the open belt drive whose length was determined using equation (6) from Khurmi and Gupta [5];

$$L = \pi(r1 + r2) + 2X + \frac{(r1-r2)^2}{X} \quad (6)$$

Where $r1$ & $r2$ = radius of smaller and larger pulleys (37.5mm, 200mm)

X = distance between the two pulleys (400mm)

$L = \pi(0.0375 + 0.2) + 2(0.4) + \frac{(0.0375-0.2)^2}{0.4} = 1.61m$



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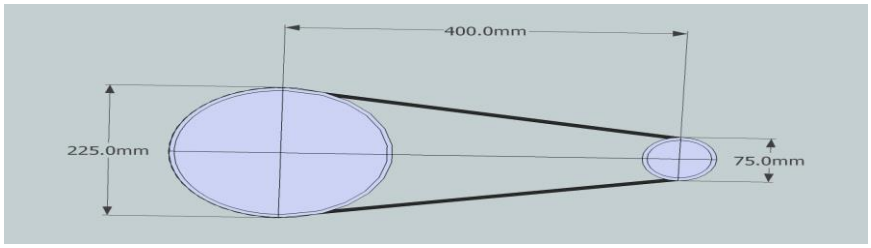

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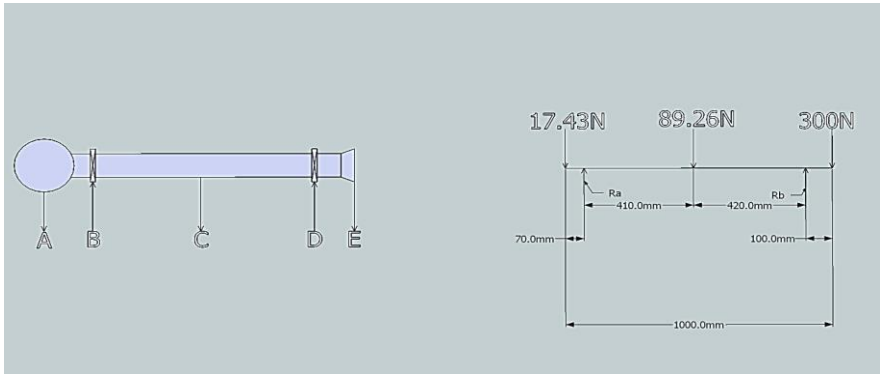

2c

Fig. 2.Schematic diagram of the (a) Pulley system, (b) Belt drives, and (c) Shaft of the extruder

Power Transmission: Power transmitted by belt drive was determined using eqns. (7), (8), (9) and (10) in accordance with Khurmi and Gupta [5];

$$P = (T_1 - T_2)\, V\, (watts) \quad (7)$$

Where T_1 = Tension in the belt on the tight side
T_2 = Tension in the belt on the slack side
V = Velocity of the belt
Ratio of driving tension for V-belt drive;

$$2.3\log \frac{T_1}{T_2} = \mu\theta\, cosec\beta \quad (8)$$

Where, μ = coefficient of friction between belt and pulley
θ = angle of contact in radians
β = half of the groove angle (Groove angle, 2β, is usually between 32° to 38° to avoid loss of power due to pulling of belt and excessive wear due to friction and heat) [5].
Let's assume 2β = 34°, therefore β is 17°

$$\sin\alpha = \frac{r_1 - r_2}{X} \quad (9)$$

Sin α = $\frac{200-37.5}{400}$ = 0.406
α = $\sin^{-1}(0.406)$ = 24°
Therefore angle of contact is;

$$\theta = (180^\circ - 2\alpha)\frac{\pi}{180}\ \text{rad}, \quad (10)$$

θ = (180 – 2(24)) x $\frac{\pi}{180}$ = 2.3rad
The coefficient of friction (μ) between the rubber belt and the dry cast iron pulley is given as 0.3
Assuming power to be transmitted is given as 1.49kw, therefore
1.49 = $(T_1 - T_2)\ 1.05$
$T_1 - T_2 = 1.42$
From equation (8), we have; 2.3Log$\frac{T_1}{T_2}$ = $0.3 \times 2.3 \times cosec17°$
$log\frac{T_1}{T_2} = \frac{0.3\times2.3\times3.42}{2.3}$
$\frac{T_1}{T_2} = 10^{1.026} = 10.62$
$T_1 = 10.62T_2$
T_1 = 1.59N, T_2 = 0.15N

Design of the Shaft: The diameter of the shaft (Fig. 2c) was determined using eqns. (11), (12), (13), (14) and (15) in accordance with Khurmi and Gupta [5].

$$T_e = \sqrt{(Km \times M)^2 + (Kt \times T)^2} \quad (11)$$

$$M_e = \frac{1}{2}(Km \times M + \sqrt{(Km \times M)^2 + (Kt \times T)^2}) \quad (12)$$

$$T = (T_1 - T_2)\,R \quad (13)$$

$$T = \frac{\pi}{6} \times t \times d^3 \quad (14)$$

$$M = \frac{\pi}{32} \times \sigma \times d^3 \quad (15)$$

Where, T_e = equivalent twisting or torsion (torque); M_e = equivalent bending moment; M = bending moment; T = torsion or twisting moment; d = minimum diameter required
t = shear stress, 42Mpa for shafts with allowance for keyways [5].
σ = normal stress, 84Mpa for shafts with allowance for keyways [5].
R = radius of bigger pulley (driven pulley)
Using eqns. (11) – (13), the twisting moment to which the shaft is subjected to was determined, given T_1 = 1.59N, T_2 = 0.15N, R = 200mm,
Therefore, T = $(1.59 - 0.15)\ 200$
T = 288Nmm = 0.288Nm

The load is assumed to be uniformly distributed along the effective length of the shaft, which comprises of the weight of the screw and that of the mixture each derived as described by Ugoamadi and Ihesiulor [7]
Weight of screw = 20N
Weight of mixture = 136.16N
Total Weight = 20N + 136.16N = 156.16N
Die weight = 300N

From Fig. 2c,
Weight at point A = Weight of pulley + tension on tight and slack sides = 17.43N
Therefore, $R_b + R_d$ = (17.43 + 156.16 + 300) N
Taking moments at point B,
$R_d \times 0.83 + 17.43 \times 0.07 = 156.16 \times 0.41 + 300 \times 0.93$
R_d = 411.81N and R_b = 61.78N
Weight of the bearings is 411.81N and 61.78N
Resultant bending moment on the screw shaft is given as $M_b = 300N\ x\ 0.93 = 279Nm$

Maximum bending moment on screw shaft is 279 Nm

$$Me = \frac{1}{2}\left(1.5\ X\ 279 + \sqrt{(1.5\ X\ 279)^2 + (1.0\ X\ 0.71663)^2}\right) = 837Nm$$

$$d = \sqrt[3]{\frac{32\,x\,M}{\pi\,x\,\sigma}} = \sqrt[3]{\frac{32\ x\ 837}{\pi\,x\,84\,x10^6}} = 0.04665m = 46.65mm$$

$$Te = \sqrt{(1.5\ X\ 279)^2 + (1.0\ X\ 0.71663)^2} = 418.5Nm$$

$$d = \sqrt[3]{\frac{T\,x\,6}{\pi\,x\,\tau}} = \sqrt[3]{\frac{418.5\,x\,6}{\pi\,x\,42\,x10^6}} = 0.0267m = 26.7mm$$

Hence the standard diameter of shaft was chosen as 60mm from the list of available size and a bright mild steel material.

Design of Screw Conveyor: The screw is made up of 3 zones, which are: the feed zone, the compression zone, the metering (pumping) zone. Figure 3 shows a schematic diagram of the zones of the screw.

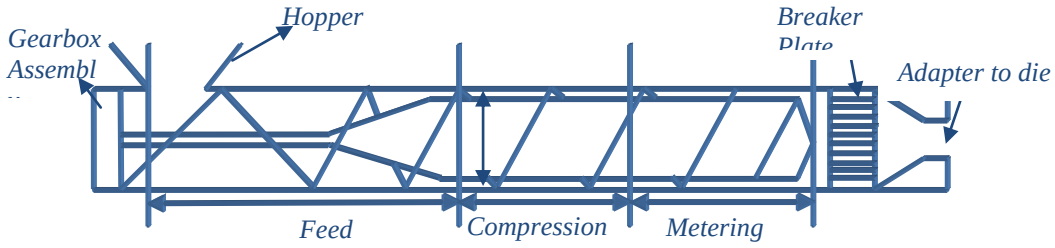

Fig. 3: Schematic diagram of the screw conveyor

According to Anonymous [4], the L/D $\left(\frac{useful\ flight\ lenght\ of\ screw}{screw\ diameter}\right)$ ratio of the screw for thermoplastic extruder ranges from 25:1 to 35:1, and extruders are described according to the outside diameter of their screw ranging from 25mm to 300mm. As a result, an L/D ratio of 30:1 and a screw diameter of 30mm were selected. Hence the flight length of the screw was determined as;

Useful flight height = $\frac{screw\ diameter \times 30}{1} = \frac{30 \times 30}{1} = 900mm$

The flows in the extruder were analysed according to eqns. (16) – (20) described by Anonymous [4] and Oswald and Hernandez [6];

Total flow = Drag flow (Q_d) – Pressure flow (Q_p) – Leak flow (Q_l). (16)

$$\text{Drag flow } (Q_d) = \frac{1}{2}\pi^2 D^2 N sin\emptyset cos\emptyset H \quad (17)$$

Where,

D = Screw diameter = 50mm
H = Channel depth of screw = $\frac{Internal\ Diameter\ of\ barrel - Diameter\ of\ screw}{2}$
Internal diameter of barrel = 73mm
H = $\frac{73-50}{2} = 11.5mm$
N = Screw rotational speed = 268rpm = 4.5 rps
Ø = Helix angle but Pitch = πDtanØ, pitch = 50mm
Ø = 17.65^o

Therefore, Drag Flow is 1.85 x 10^{-4} m^3/s

$$\text{Pressure flow } (Q_p) = \frac{\pi D H^3 Sin^2\emptyset}{12\eta}\left(\frac{dp}{dl}\right) \quad (18)$$

Where,

dp = Pressure drop along extruder

dl = Length of flow path

$$\eta = \text{Fluid viscosity} = m(T°c)\gamma^{n-1} \quad (19)$$

With, m = Consistency Index = $6 \times 10^3 (Pa - s)^n$

n = Power Law Index; n = 0.39

γ = Shear Rate = $\frac{Velocity}{Channel\ depth} = \frac{1.67 \times 10^{-4}}{3.5 \times 10^{-3}} = 0.048 s^{-1}$

$\eta = 7.6 \times 10^6 pa.s$

Pressure Flow **was found to be 5.54 x 10^{-13} m^3/s**

$$\text{Leak flow } (Q_l) = \frac{1}{12\eta} \frac{\Delta p}{e cos\emptyset} \frac{\pi D}{cos\emptyset} \delta^3 \quad (20)$$

Where, H = δ = Depth of silt

e = width of screw flight

Note: Leak flow is insignificant compared to drag flow and pressure flow and may be neglected in finding total flow

Design of Barrel: An efficient barrel cooling system is important to control the tendency for mechanical shear heat developed in the melt to override the electrical heater controls. The optimal extruder barrel length is 30-32 times its internal diameter (30:1 L/D, 32:1 L/D). Although shorter barrels can be used, but mixing efficiency and melt uniformity may not be optimal. Cooling to the extruder feed throat is provided by a rotating fan to prevent surging or bridging. Internal cooling to the screw is not needed.

Assumptions

The outer diameter and internal diameter of barrel were chosen as **88mm and 73mm** respectively, therefore length of barrel will be 73mm times 32 which is equal to **2336mm.** The thickness of the barrel is 15mm to withstand the escape of heat through the barrel.

Design of Heating Bands: The mixture of the plastic and wood material must be processed at a temperature at or below the thermal degradation of the wood fibres, normally 200 to 220℃ (392 to 428°F), and most plastics are processed between temperatures between 163℃ & 200℃ even though melting can occur between 108 to 121℃ [7, 11]. The target temperature was chosen as 180℃ for the barrel. Hence, the mixture must be raised from room temperature (25℃) to the target temperature (180℃) and the polyethylene material acts as the binding agent in the mixture, it flows when heated allowing proper mixing of the mixture, the heat needed to raise the temperature of the material from 25℃-180℃ was determined using eqn. (21) as described by Ugoamadi Ihesiulor [7];

$$Q_{25℃\text{-}180℃} = MC_P\Delta t_1 + ML + MC_P\Delta t_2 \quad (21)$$

Where, M = Mass of material

C_P = specific heat capacity of polyethylene material (2.004 KJ/Kg.K)

L = Specific latent heat of fusion (74.8 KJ/Kg)

Q = $13.88 \times 2.004 \times (121 - 25)℃ + 13.88 \times 74.8 + 13.88 \times 2.004 \times (180 - 121)℃$

Q = 2670.29 + 1038.22 + 1641.12

Q = 5349.63KJ

The heat source must be able to generate this amount of heat and the amount of heat that will be lost through the walls of the heating chamber.

Fabrication and Assembly of the Machine

The single screw extruder parts such as the hopper, the barrel, the stands and the screw were fabricated and assembled at the Faculty of technology technical workshop, university of Ibadan, Ibadan Nigeria. The process undertaken during the operations include, marking out, cutting, beating, sharpening, drilling, boring and welding.

Fabrication and Performance Test the Machine

Following the design, fabrication and assembly of the machine, the performance of the single-screw extruder was evaluated. The machine was prepared for the extrusion operation by first switching on the heater (i.e. the heating element). The heating lasted for 45mins to enable the barrel reach the heating temperature of 180℃. The sorted samples comprising of both plastic and *melina arborea* sawdust at different compositions were fed into the machine through the hopper, as the electric motor was simultaneously switched on. The time taken for recycling per batch was monitored with the use of a stop watch. A 2-Hp-3-phase electric motor was used as prime movers at specific periods of time. The time taken to recycle each quantity of plastic and sawdust varied from 5 to 10 minutes for each of the prime movers, the average performance efficiency and the capacity of the machine were estimated using eqns. (22) and (23) respectively:

$$\text{Performance Efficiency (\%)} = \frac{\text{mass of recovered material}}{\text{mass of input material}} \times 100 \quad (22)$$

$$\text{Average Capacity of machine} = \frac{\text{mass of input material (kg)}}{\text{time taken for crushing (hr)}} \quad (23)$$

Five test samples of wood plastic composites (WPC) in the ratio of Plastic/Wood of 90/10, 80/20, 70/30, 60/40, and 50/50, were produced, each in three replicates. The samples of the WPCs produced were cured for 28 days and were weighed to determine the amount of plastic and sawdust that was recycled. The sorption (Water absorption (WA) and Thickness swelling (TS) properties of the WPCs produced were determined using standard procedures. The tests were carried out according to standard methods [12].

Measurements of mass (g), thickness (mm) and length (mm) of the samples were taken prior to treatment as initial parameters while the final measurements were taken after immersion in water for 2h and 24h using electronic weighing balance, digital caliper and meter rule, respectively. The properties were estimated using the following equations (24) and (25):

Water Absorption (WA (%): $$\mathbf{WA}\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \quad (24)$$

Thickness Swelling (TS (%): $$\mathbf{TS}\ (\%) = \frac{T_2 - T_1}{T_1} \times \mathbf{100} \quad (25)$$

Where: W_1, T_1, L_1 are initial mass (g), thickness (mm), and length (mm) before treatment and W_2, T_2, L_2 are final mass (g), thickness (mm) and length (mm) after treatment, respectively.

DISCUSSION OF RESULTS

Performance Evaluation of Extruder Results

The designed Single Screw Extruder was fabricated and assembled as shown in Figure 4. The capacity of the hopper is about 38.3litres, where the materials to be extruded are fed through. When the machine was operated at a speed of 268rpm (4.5rps), the efficiency was found to be 85% with a throughput of 17.55 kg/hr and a low specific mechanical energy of 191.21kJ/kg was achieved as expected to save running cost and high energy consumption.

Operation of the Single Screw Extruder

In agreement with Dhanasekharan and kolini [13], the movement of materials from one chamber to another was hindered by the drag force by the screw. The mechanical behavior of the screw was observed as the fed materials passed through the feed throat to the compression unit where the force of compression splits and meshes granular materials until their surface areas are reduced [14]. The maximum acceleration and kinetic energy of the rotating screw at 4.5rps were observed in the compression unit. This is important, as the effective mixing or homogenization of the granular materials occur at this unit [10]. The materials gained entrance to the metering zone where they acquire enough pressure to pass through the breaker plate and into the die opening of the extruder (forming unit). This corroborates the findings of Jiang and Bi [15] and Siregar *et al.* [16].

Figure 5 shows that the lower the Specific Mechanical Energy (SME) at low speed the higher the output mass. This is as expected, as many output mass can be achieved in a longer period of time at low speed and low kinetic energy thereby leading to a reduced capacity measurement. The results showed that the lowest and highest output mass of 0.76kg and 0.88kg at specific mechanical energy of 450KJ/Kg and 200KJ/Kg respectively. Although the SME reduces with increasing output mass. The use of a lower speed for the operation of the machine will result to an increase in output mass because the loss of the material during operation will be minimal; therefore lower speeds results in lower specific mechanical energy [10].

Figure 4: Fabricated Single Screw Extruder

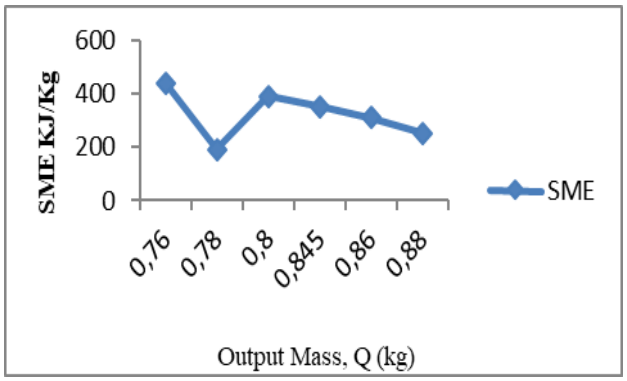

Figure 5: The Effect of Mass Output on the Specific Mechanical Energy under the Influence of Screw Speed and Torque

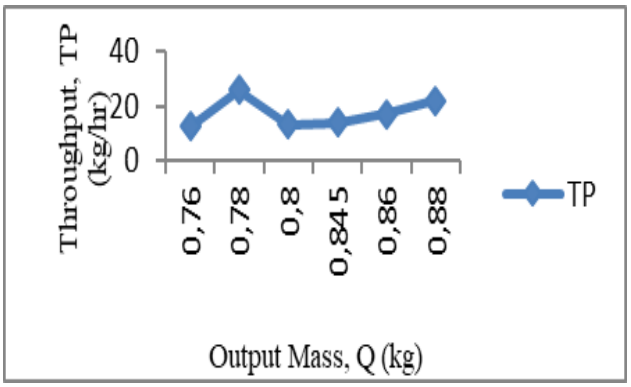

Figure 6: The Effect of the Throughput on the Mass Output of the Machine under the Influence of Screw Speed and Torque

Except for the throughput between the output mass of 0.78kg and 0.8kg (Figure 6), increase in the throughput indicates increase in the output mass provided the operation was carried out over the same length of time.

Wood-Plastic Composite Test

The results of various tests carried out to determine some physical properties of the wood-plastic composite are presented in Tables 1, 2, and 3.

Density and Mass: The volume of each sample was estimated from the nominal dimensions while the mass was determined using a weighing scale. The density of each sample was calculated in g/cm^3. The densities of the WPCs produced are presented in Table 1. The results indicated that the density ranged from 0.35g/cm^3 (350kg/m^3) to 0.95g/cm^3 (950kg/m^3). Generally, as the wood content in the composite is increased the density of composite produced also increased. This corroborates the findings of Omoniyi and Yinusa [17].

Table 1. Mean Dimensions, Mass and Densities of WPCs Produced

Sample (Plastic/Wood ratio)	***Dimensions (cm)***			*Diameter (cm)*	*Volume (cm^3)*	*Mass (g)*	*Density (g/cm^3)*
	Length	*Breadth*	*Thickness*				
***A** (90/10)*			*1.4*	*7.5*	*61.88*	*44.00*	*0.711*
***B** (80/20)*	*10.2*	*4.0*	*1.3*		*53.04*	*45.30*	*0.854*
***C** (70/30)*	*10.2*	*3.2*	*1.7*		*55.49*	*47.85*	*0.862*
***D** (60/40)*	*10.5*	*3.2*	*1.9*		*63.84*	*56.01*	*0.877*
***E** (50/50)*	*11.4*	*3.9*	*1.7*		*95.68*	*68.55*	*0.907*

Thickness Swelling (TS)

Table 2 shows the increase in thickness of the samples when soaked in water at 0h, 2h and 24h. The mean TS values ranged from 0.14 – 0.94%. Sample A has the lowest TS value while sample E has the highest value. It can be observed from the results that wood contents increased the TS also increased which may be due to the hydrophilic nature of wood. However, the TS values compared favorably with the 0.12 – 4.05%, reported by Oluyege *et al.* [18] for the TS values observed for WPCs produced from *Ceiba Pentandra* particles.

Table 2. Thickness Swelling (%) of WPCs Produced

Sample (Plastic/Wood ratio)	*Thickness (mm)*			*Thickness Swelling (%)*	
	0hr	*2hrs*	*24hrs*	*After 2h*	*After 24h*
A(90/10)	*14*	*14.02*	*14.04*	*0.14*	*0.29*
B(80/20)	*13*	*13.02*	*13.05*	*0.15*	*0.38*
C(70/30)	*17*	*17.04*	*17.10*	*0.24*	*0.59*
D(60/40)	*19*	*19.07*	*19.17*	*0.37*	*0.89*
E(50/50)	*17*	*17.07*	*17.16*	*0.41*	*0.94*

Table 3. Water absorption (%) of WPCs Produced

Sample (Plastic/Wood ratio)	*Weight (g)*			*Water absorption (%)*	
	0hr	*2hrs*	*24hrs*	*After 2hrs*	*After 24hrs*
A(90/10)	*44*	*44.2*	*44.70*	*0.45*	*1.59*
B(80/20)	*43*	*43.3*	*43.80*	*0.70*	*1.86*
C(70/30)	*42.25*	*43.05*	*43.31*	*1.89*	*2.51*
D(60/40)	40	42.4	44.10	6.00	10.25
E(50/50)	38	40.25	43.20	5.92	13.68

Table 3 presents the WA for the WPCs produced. From the results presented, the WA values ranged from 0.45 – 13.68%. Sample A, which contains 10% sawdust of *melina arborea* in its components has the lowest value for WA while the highest value was observed for sample E with 50% wood fibre contents. Although other samples have low water absorption, however, there are significant differences in the (2h) and (24h) periods of soaking. The results also indicated that as the wood content increased in the mixing ratio, the WA also increased. Water absorption of composite is an important factor in classifying its durability and composites of low water absorption will afford better protection to reinforcement within it [19].

The WPCs produced where smooth in appearance and insignificant coarseness only felt and may not be visible. This implies a proper blend and mixture of the granular materials by the machine indicating the effectiveness of the machine designed and fabricated. It can be inferred from the findings that the sorption (WA and TS) properties of the WPCs produced were as a result of the components mixed and the time of soaking and not as a result of the machine fabricated.

CONCLUSION

The need to reduce the effects of environmental pollution by plastic materials littering the surroundings and wood wastes materials used as landfills or burnt causing green-house effects, brought about the implementation of the idea to design and fabricate a laboratory scale single screw extruder that can be used to turn these wastes to wealth. The design and fabrication of the machine was successfully carried out and the performance evaluated. The performance test showed the machine had an efficiency of 85% and an output capacity of 17.55kg/hr. The WPC produced using the extruder showed sorption properties which compared favorably with some reported in literature for WPCs recommended for indoor applications. Hence the designed aim of the study has been achieved by designing and fabricating a single screw extruder which can be used for recycling waste pure water sachets, plastic bottles and wood wastes (sawdust).

REFERENCES

[1] Einwood, 2010. Wood plastic composites: a material of the future.

[2] Maiju Hietala. 2011. Extrusion Processing of Wood Raw Materials for Use in Wood-Polymer composites. Lulea Univ. of Technology, Lulea, Swden. pp.1-18.

[3] Brandrup J., 1996. Recycling and recovery of plastics. Hanser Publisher Verlag. ISBN-10:3446182586. pp.1-927.

[4] Anonymous ,1955. Description and analysis of polymer flow in extruders. http:// www.kmutt.ac.th/p-prof/P-PROF%2520w... Assessed on 28/04/2020.

[5] Khurmi, R.S., and Gupta, J.K., 2005. A Text Book of Machine Design, Eurasia Publishing House (PVT) Ltd. India, pp 1-1251

[6] Oswald, T. and Hernandez, J.P. 2006, *Polymer Processing – Modeling and Simulation,* Polymer Processing – Modeling and Simulation, 1st Edition. Munich Hanser Verlag.

[7] Ugoamadi C.C. and Ihesiulor O.K, 2011. Optimization of the development of a plastic recycling machine. *Nigerian Journal of technology*, Vol 30, No 3.

[8] Nwaigwe K.N, Nzediegwe .C, Ugwuoke P.E., 2012. Design, Construction and Performance Evaluation of a Modified Cassava Milling Machine. Research Journal of Applied Sciences, Engineering and Technology 4(18): 3354-3362.2012 ISSN: 2040-7467, © Maxwell Scientific Organization, 2012.

[9] Odior A.O., Oyawale Festus A. and Odusote Joe K., 2012. Development of a polythene recycling machine from locally sourced materials. Industrial Engineering Letters, ISBN 2225-0581 (online), Vol 2, No. 6, 2012. Pp 42 – 46

[10] Fadeyibi, A., Osunde, Z.D., Agidi, G., and Egwim, E.C., 2016. Design of Single Screw Extruder for Homogenizing Bulk Solids. *Agricultural Engineering International: CIGR Journal*, 18(4), 222-231

[11] Wood Handbook 2010. Wood as an Engineering material, April 2010

[12] ASTM D570, 2018. Standard Test Method for Water Absorption of Plastics. West Conshohocken: ASTM

[13] Dhanasekharan, K..M., and Kokini, J.L., 2003. Design and scaling of wheat dough extrusion by numerical stimulation of flow and heat. *Journal of food Engineering*, *60*(4), 421-430

[14] Petrou, M., Novak, O., Hera, D., and Simanjuntak, S., 2012. Finite element method model of the mechanical behaviour of *Jatropha curcas* L. seed under compression loading. *Biosystems Engineering*, 111(1), 412-430

[15] Jiang, B., and Bi, C. 2009. Study of residence time distribution in a reciprocating single screw pin-barrel extruder. *Journal of Materials Processing Technology*, 209(8), 4147-4153.

[16] Siregar, N.A., Mamhood, W.M., Ghani, J.A., Haron, C.H., and Rizal, M. 2014. Design and Analysis of Single Screw Extruder for *Jathropha* Seeds Using Finite Element Method. *Research Journal of Applied Sciences, Engineering and Technology*, 7(10), 2098-2105.

[17] Omoniyi, T.E., and Yinusa, R.O. 2018. Development of Processing Equipment for Souvenir Production from Wood and Plastic Wastes. *Proceeding of 6th NSCB Biodiversity Conference Uniuyo*, 2018, 390-386.

[18] Oluyege, A., Ekong, A., Aguda, L., Ogunleye, B., Abiola, J., and Olayiwola, Y. 2017. Physical and Mechanical Properties of Wood Plastic Composites Produced from Sawdust of *Ceiba pentandra* (L.) Gaerten. and Plastic Wastes. *Journal of Forestry Research and Management, 14*(2), 95-112.

[19] Omoniyi, T.E., Akinyemi, B.A., and Fowowe, A.O. 2014. Effects of Waste Glass Powder as Pozzolanic Material in Saw Dust Cement Brick. *Scholars Journal of Engineering and Technology (SJET)* 2(4A), 517-522.

RAZVOJ EKSTRUDERA SA JEDNIM VIJAKOM ZA PROIZVODNJU DRVENO-PLASTIČNOG KOMPOZITA

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Sažetak: Ova studija prikazuje projektovanje, proizvodnju, sastavljanje i procenu performansi mašine ekstrudera sa jednim vijakom za drvno-plastične materijale (WPC) koji se može koristiti za reciklažu drvnog i plastičnog otpadnog materijala koristeći ove materijale iz lokalnih izvora, na osnovu raspoloživosti i isplativosti.

Ekstruder ima četiri celine-jedinice predviđene za: prijem materijala, transport, zagrevanje i oblikovanje. Dizajnirani delovi su: kapacitet prijemnog koša, prečnik pužne osovine, dimenzije vijka (korak, ugao i prečnik zavojnice pužnog elementa) i kapacitet transportera (jedinica za dovod, kompresiju i doziranje). Razvijena mašina je procenjena kod upotrebe u ekstrudiranju plastičnog otpada male gustine i piljevine stable biljke gmelina (*Gmelina arborea)*. Rezultati su dobijeni za kapacitet prijemnog koša od 38,3 m^3, prečnik osovine od 60 mm, i dimenzije pužnog vijka (prečnik = 20 mm, korak=50 mm i ugao zavojnice = $17,65^0$).

Procena performansi mašine pokazala je efikasnost od 85% za mašinu pri radnoj brzini od 268 o/min (4,5 o/min) sa protokom materijala d 17,55 kg/sat za maksimalni period od 5 minuta. Srednja adsorpcija vode (0,45-13,68%) i porast debljine (0,14 - 0,94%) zabeleženi su kod proizvedenih kompozita i upoređeni su povoljno sa onima koji su u literaturi navedeni za WPC preporučene materijale. Sadržaj drveta i period kvašenja uticali su na adsorpciona svojstva, a ne na efikasnost ili neefikasnost mašine.

Mašina štedi troškove i energiju zahvaljujući niskoj specifičnoj potrošnji mehaničke energije od 191,21 kJ/kg.

Ključne reči: *kompozit od drveta i plastike, ekstruder sa jednim vijkom, obnovljivi materijali, efikasnost, kapacitet, specifična mehanička energija.*

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EFFECT OF PROCESS CONDITIONS ON SANDBOX SEED OIL YIELD BY MECHANICAL EXPRESSION: A RESPONSE SURFACE APPROACH

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Abstract: Cost of solvent oil extraction methods has made mechanical oil expression a desirable alternative. The effect of process variables on mechanical oil expression from sandbox seed was studied. The experimental design used for the study was a 5^2 Central Composite Rotatable Design of Response Surface Methodology. Experimental factors considered were: moisture content, roasting temperature, roasting time, expression pressure and expression time. Results obtained were analyzed at $\alpha_{0.05.}$ The oil yield from the sandbox seed ranged from 16.38-38.68%, and was increased at processing variable ranges of (4.0-8.0%) moisture content, (80.0-90.0^{o}C) roasting temperature, (5.0-15.0%) roasting time, (15.0-20.0 MPa) expression pressure and (6.0-8.0 min) extraction time. The maximum oil yield of 38.68% was obtained at the processing conditions of 6% moisture content, 85 ^{o}C roasting temperature, 15 min roasting time, expression pressure of 20 MPa and 8 min pressing time. Model equation relating the process variables to oil yield was developed. Coefficient of determination (R^2) relating the process was 0.8908. The result showed that moisture content, roasting time, expression pressure and expression time had a significant influence on the sandbox oil yield. The results obtained in this study can serve for process and equipment designs for oil extraction from sandbox and other oilseeds and nuts.

Keywords: *Sandbox seed, mechanically expression, oil expression, oil yield, Response surface*

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INTRODUCTION

The sandbox (*Hura crepitans* Linn.) is a tree of the (*Euphorbiaceae*) family indigenous to the American continent. It is an evergreen dicotyledon perennial tree also known as *possum* wood and *jabillo*. Sandbox fruit is pumpkin-like shaped with capsules, 3-5 cm long and 5-8 cm diameter, arranged radially in carpel of 14-16 seeds.

The seeds are flattened, about 2 cm in diameter [9, 19]. In some places, sandbox leaves are used for medicinal purposes, but the seed has not been fully exploited and utilized [3]. However, the rich oil content of the sandbox seed has been established [13, 5]. The properties, proximate composition and chemical characterization of sandbox seed and its oil have been studied [13, 19, 10]. According to [13, 21], sandbox seed contains properties with industrial and pharmaceutical application potential and can be utilized for feed, paints, and cosmetics amongst others. However, sandbox is still regarded as an underutilized plant in Nigeria and some other parts of the world, which is planted as shade trees [1]. Previous studies on oil extraction from sandbox seeds focused mainly on solvent extraction [18, 23, 24, 19]. Oil extraction by solvent methods has become attractive for some oilseeds as it can recover up to 98% of oil [16]. However, the cost of solvent extraction has made mechanical expression one of the best alternatives for extracting oil from oil seeds and nuts. Thus, oil expression by mechanical means has been carried out on many agricultural products viz: roselle [4]; soybean [17]; neem [22]; avocado and sunflower [26]; rice bran [25]; coconut [12]; shea butter [20]; sesame [2]; *Moringa* [8] amongst others. The quantity and quality of extractable oil from oilseeds is first a function of the seed quality before extraction [17], then the effectiveness of the expression machine and process handling. Other factors include process parameters such as material moisture content, unit size, roasting temperature and time, expression pressure and time of extraction. These treatment variables immensely influence oil yields from oil-bearing materials by mechanical methods [15]. Thus, it is very vital that these parameters are controlled during expression for optimum oil yield [4].

Information is however scarce regarding oil extraction by mechanical means from sandbox seed. To further develop the mechanical oil expression process from sandbox seed for both commercial and industrial applications, there is need to quantify the oil yield as influenced by the processing parameters using the Response Surface Methodology (RSM). The RSM was developed as a suitable analytical instrument for optimization of process variables through the use of Central Composite Design (CCD), Box-Behnken design and D-optimal experimental designs [11]. RSM has been described as an effective method in relating the interaction of individual variables such as moisture content, roasting temperature and time, expression pressure and duration relatively to oil yield. Better than the conventional methods, the RSM utilizes minimal experimental runs to predict a combination of process variables for optimal result(s) and also develops mathematical expression(s) relating the variables and response(s) [11]. With this understanding, models can be developed from experimental procedures to predict oil yields from oil-bearing materials relatively to process variables. To effectively quantify

the oil yield from sandbox seed by mechanical expression, effects of process variables such as moisture content, roasting temperature and time, expression pressure and time on oil yield were evaluated.

MATERIALS AND METHODS

Design of experimental

The influences of process variables: moisture content, roasting temperature and time, expression pressure and time on oil yield from sandbox seed by mechanical expression were evaluated.

These selected variables are among the significant factors that influence mechanical oil expression [8]. A 5^2 factorial Central Composite Rotatable Design (CCRD) of RSM experimental design developed by [7] was adopted for the experiment. The lower limit of the CCRD dropped the total number of design points to 32 runs, which consist of 16 factorial CCD, 10 axial points and 6 replications of the center points. The moisture content levels selected for this experiment was a function of the moisture content of matured sandbox seeds. The ranks of other variables selected were based on preliminary experiments carried out and previous results from research works on many oil seeds and nuts as information was not found regarding the relationship of processing factors on oil yield from sandbox seed by mechanical expression. Five levels of moisture content, *mc* [4, 6, 8, 10 and 12% wet-basis (wb)], roasting temperature, τ_{tp} (80, 85, 90, 95 and 100^{o}C) and time, τ_{tm} (0, 5, 10, 15 and 20 min), expression pressure, ε_{Pr} (5, 10, 15, 20 and 25 MPa) and time, εx_{tm} (2, 4, 6, 8 and 10 min) on the sandbox oil yield were evaluated.

Development of laboratory screw press

A laboratory screw press (Fig. 1) was developed and used for the oil expression. The five barrel press was designed for 25MPa maximum capacity, with a barrel capacity of 1810 cm^3. The screw press pressure was calibrated as a function of the pitch diameter. Preliminary test was conducted; 500 gram sample of the ground sandbox was placed into the barrel. The press was screwed until the screw could not move any further. That point was marked on the meter rule as the 25 MPa mark. Pitch graduation was used to mark the screw to represent 20, 15, 10 and 5 MPa respectively. The multiple barrel press was designed so as to make the work easier and faster.

Fig. 1. Screw press

Fig. 2. Sandbox kernels

Sample preparation

Dried and mature sandbox fruits were collected and the kernels extracted (Fig. 2).

Moisture content determination

Initial moisture content of the sandbox seeds was determined by ASABE standards for oven drying method as adopted by [8] for African star apple and Moringa seeds respectively. The moisture content, *mc* (wet-basis) was calculated from Eq. (1).

$$\text{MC}\ (\%\,\text{w.b.}) = \frac{\text{W}_\text{i} - \text{W}_\text{f}}{\text{W}_\text{i}} \times 100 \qquad (1)$$

W_i = sample initial weight and W_f = sample final

Samples of one kg each of the sandbox seeds were subjected to the required moisture content levels by Eq. (2) as adopted by [8].

$$\text{Q} = \left(\frac{100 - \text{S}_\text{i}}{100 - \text{S}_\text{d}} - 1\right) \times \text{W}_\text{s} \qquad (2)$$

Q = Amount of moisture to be absorbed (ml);
S_i = sample's initial moisture content (%wb);
S_d = sample's required moisture content (%wb);
W_s = Sample's weight (g)

Afterwards, the samples already conditioned were wrapped in a cloth, tied in nylon bags and refrigerated at 5 °C for two days for even circulation of required moisture and transferred into a desiccator to avoid moisture migration until the commencement of the experiment.

Experimental procedures

A 500 g ground samples each was used for the various experiments. Samples were roasted at the stipulated temperature and time and fed into the extraction chamber (barrel) and pressed at stipulated pressures and times. Triplicate experiments were carried out. The oil was expressed into a container and left for 3 days before weighing and the oil yield was calculated using Eq. (3) as adopted by [8] for determination of percentage oil yield from Moringa.

$$\text{Oil Yield}\ (\%) = \frac{\text{Wieght of oil expressed}}{\text{Wieght of sandbox seed sample before pressing}} \times 100 \qquad (3)$$

Response Surface Methodology (RSM)

An RSM Design Expert software package (version 6.0.6) was used for the experimental design. Ranges of the experimental variables were fixed into the software to generate the combination of process factors for the experiments. The generated combinations were used for the oil expression. The oil yield got from each run was inputted as the response for that combination. These outcomes were subjected to the models of the software package which include the linear, the two factorial interactions (2FI), the quadratic and the cubic models respectively. The statistics in terms the probability of error value (p-value) and coefficient of determination (R^2) which are indicators on how well the interactions between processing variable influenced the response (oil yield) were used in selecting the best model for the process. The selected model was analyzed using Analysis Of Variance (ANOVA) in order to ascertain the

level of significance and fitness of the model in interpreting the correlation between the process factors and the oil yield (response). Windows 20.0 SPSS statistical software package was used to analyze the tests of between-subjects effects of process conditions on oil yield.

RESULTS AND DISCUSSION

The initial moisture content of the sandbox seed was obtained as 6.12% wb. The average oil yield at various process conditions are presented in Table 1. The relationship of the process parameters on oil yield are shown in Figs. 3-5. The oil yield from the sandbox seed ranged from 16.38-38.68%.

Table 1. Oil yield from sandbox seed at various processing conditions

Run	Factor 1 A: mc (%)	Factor 2 B: τ_{tp} (%)	Factor 3 C: τ_{tm} (min)	Factor 4 D: ε_{Pr} (MPa)	Factor 5 E: εx_{tm} (min)	Response Oil yield (%)
1	8	90	10	15	6	36.14
2	6	85	5	10	8	32.77
3	6	95	15	10	8	35.09
4	10	95	15	10	4	23.66
5	8	90	10	15	2	16.38
6	8	90	10	15	6	35.00
7	10	85	15	20	4	24.43
8	8	90	10	15	10	37.02
9	8	80	10	15	6	32.66
10	4	90	10	15	6	32.22
11	8	90	10	15	6	36.22
12	6	85	15	10	4	24.68
13	8	90	10	15	6	35.00
14	10	95	5	20	4	19.44
15	10	85	5	20	8	25.00
16	8	100	10	15	6	36.00
17	6	95	15	20	4	25.00
18	6	95	5	10	4	21.66
19	8	90	20	15	6	34.33
20	8	90	10	15	6	36.77
21	10	95	15	20	8	32.88
22	8	90	10	5	6	18.66
23	8	90	10	25	6	30.00
24	12	90	10	15	6	20.49
25	6	95	5	20	8	30.66
26	10	85	5	10	4	24.99
27	8	90	10	15	6	35.66
28	8	90	0	15	6	18.62
29	10	95	5	10	8	32.54
30	10	85	15	10	8	34.65
31	6	85	15	20	8	38.68
32	6	85	5	20	4	23.11

mc = moisture content of sandbox seed, τ_{tp} = roasting temperature, τ_{tm} = roasting time, ε_{Pr} = expression pressure and εx_{tm} = extraction time

For the range of process variables considered in this study, the oil yield greatly increased at the processing variable ranges of (4.0-8.0%) moisture content, (80.0-90.0^{o}C) roasting temperature, (5.0-15.0%) roasting time, (15.0-20.0 MPa) expression pressure and (6.0-8.0 min) expression time.

The highest oil yield of 38.68% was obtained at 6% wb moisture content, 85 ^{o}C roasting temperature, 15 min roasting time, expression pressure of 20 MPa, at 8 min pressing time. Relatively to solvent extraction of oil from sandbox seed; 57.26% and 53.61% oil yield was obtained using n-hexane at reaction temperature range of (40-60 ^{o}C), [23, 19]; 42.70% oil yield was obtained using petroleum ether at (40-60 ^{o}C) reaction temperature [18].

Higher oil yield by solvent extraction in comparison to other extraction methods may be due to the solvent penetration capability to solubilize the lipid within the cell structure, thereby extracting as much oil as possible [6]. However a lower oil yield of 37.75 and 36.70% respectively were obtained using n-hexane [4, 24]. The differences in oil yields occur as a result of the extraction methods used, and also, due to biological and environmental conditions [8].

Increase in moisture content from 4-8% wb showed a substantial increment in the oil yield. However, oil yield was observed to decrease at moisture content beyond 8% wb (Fig. 3). Moisture addition enhances the rate at which particles reach their saturation points during expression.

However, at excess moisture, the expression pressure is absorbed by the liquid phase without getting to the oil cells, hence, reducing oil yield [25]. Therefore, the optimum moisture content for mechanical expression of oil from sandbox seed was obtained as 8% wb beyond which there was reduction in oil yield (Fig. 3). This agrees with findings on oil seeds and nuts such as neem, avocado, and roselle amongst others as the most appropriate moisture level for screw press extraction of oil [22, 26, 4].

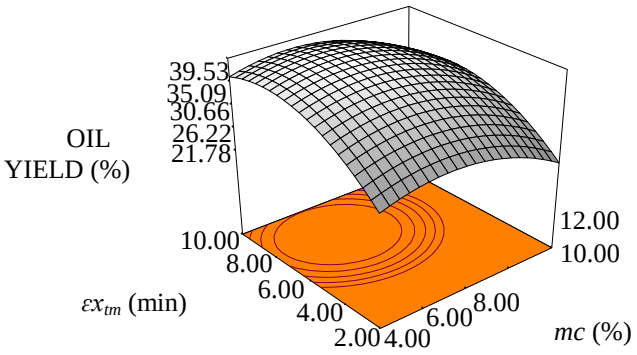

Fig.3. Extraction time and moisture content against oil yield

The oil yield increased at the roasting temperature range of 80-90 ^{o}C, after which a decrease was observed at the roasting temperatures of 90-100 ^{o}C (Fig. 4). Lower heating

temperatures have been suggested to be insufficient heat treatment to release sufficient oil from samples. Also, excess heat treatment hardens seeds and nuts, bringing about resistance to applied pressure during expression, thereby leading to drop in oil yield [8]. The 90 ^{o}C optimum roasting temperature obtained for sandbox seed was similar to 81.93 ^{o}C reported for groundnut [20], and 90 ^{o}C for African oil bean seed.

Sandbox seed is a soft texture seed that 90 ^{o}C roasting temperature was adequate to penetrate the seed for maximum oil yield.

Finding from [4] agrees with this temperature trend obtained for sandbox seed and affirmed it to the simultaneous reduction in seed moisture, oil viscosity and protein coagulation by the addition of heat which assists oil expression process. Substantial moisture loss occurs at higher temperature, leading to hardening of oil seed sample, thus causing reduction in oil yield.

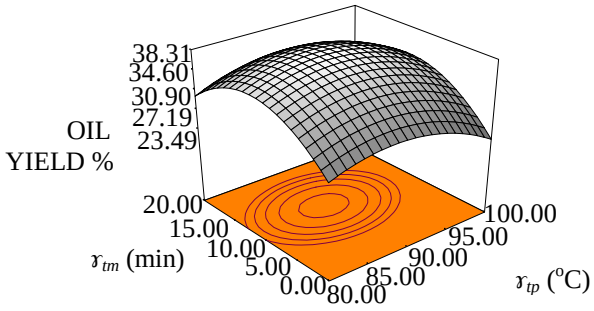

Fig. 4. Roasting time and roasting temperature against oil yield

The oil yield increased as the roasting time increased from 0-15 min. The oil yield was least at 0 minute roasting time (the un-roasted sample) and increased as roasting time increased up to 15 min beyond which a decrease was observed (Fig. 5). The oil yield was lowest for the unroasted samples, indicating the importance of heat treatment on oilseeds before oil extraction. Also, extended heating beyond 15 min roasting period decreased the oil yield. Flowability of oil varies kinematic viscosity inversely. Therefore, the decrease in kinematic viscosity as heating temperature increases enhances the release of oil [14].

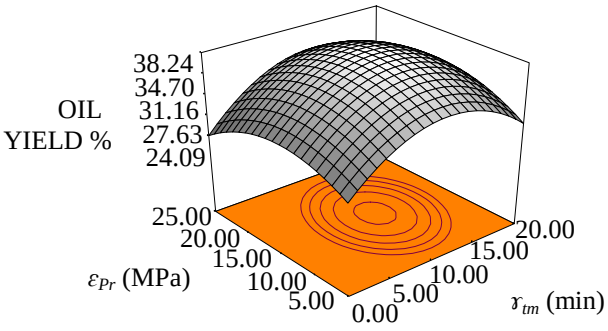

Fig. 5. Expression pressure and roasting time against oil yield

For oilseeds, heat treatment at lower temperatures required more time for moisture alteration which causes the collapse of oil capillaries, coalescence of protein and increase in oil fluidity, whereas, heat treatment at higher temperature takes shorter time to achieve same [8].

The highest oil yield for the sandbox seed was obtained when seed samples were roasted at 85 ^{o}C for 15 min (Figs. 3, 5). Similar finding was reported for sesame [2] amongst others.

Oil yield greatly increased at expression pressure of 5 MPa up to 20 MPa. There was however a decline in oil yield as the expression pressure increased to 25 MPa (Fig. 5). This may be related to the crushing of oil bearing pockets of the sandbox which sealed off some inter-cell spaces at increased pressure. Also, the mash formed a slurry paste which blocked the perforated oil holes on the expression machine while some flowed above the pressing base at pressure above 20 MPa. As observed by [4], increase in pressure during oil expression increases pressure on the seed cell wall, thereby rupturing them in the process to release their contents. However, continuous increase in pressure on oil seeds during expression continually compress, disrupt and may ultimately close the oil bearing vessels [27]. The observation on sandbox seed is in tandem with the findings for rice bran, melon, roselle, soybean [25, 2, 4, 17] amongst others.

There was increased oil yield as expression time increased from 2 min up to 8 min and decreased at expression time beyond 8 min (Fig. 3). Similar observation was reported for soybeans [17].

Table 2. Model Comparison

	Models			
Statistics	*Linear*	*2FI*	*Quadratic*	*Cubic*
Standard deviation	*4.84*	*5.86*	*3.72*	*2.21*
R^2	*0.5623*	*0.6053*	*0.8907*	*0.9789*
Mean	*29.39*	*29.39*	*29.39*	*29.39*
Adjusted R^2	*0.4781*	*0.2353*	*0.6921*	*0.8909*
Coefficient of Variation	*16.47*	*19.93*	*12.65*	*7.53*
Predicted R^2	*0.3910*	*-2.1284*	*-1.8079*	*-19.9477*
PRESS	*847.71*	*4352.06*	*3906.19*	*29140.84*
Adequate Precision	*9.272*	*5.449*	*7.280*	*10.349*

FI = Factorial Interaction,
PRESS = Predicted Sum of Square.

The equation predicting oil yield from sandbox seed and the processing parameters is as shown in (Eq. 5).

$$OY = 35.35 - 1.5mc - 0.03\gamma_{tp} + 2.5\gamma_{tm} + 0.49\varepsilon_{Pr} + 4.8\varepsilon x_{tm} - 1.91mc^2 + \\ + 0.086\gamma_{tp}^{\ 2} - 2.41\varepsilon_{Pr}^{\ 2} - 1.83\varepsilon x_{tm}^{\ 2} + 0.39mc\gamma_{tp} - 0.098mc\gamma_{tm} - 1.09mc\varepsilon_{Pr} - \\ -.64mc\varepsilon x_{tm} - 0.27\gamma_{tp}\gamma_{tm} + 0.058\gamma_{tp}\varepsilon_{P} + 0.47\gamma_{tp}\varepsilon x_{tm} + 1.04\gamma_{tm}\varepsilon_{Pr} + 0.74\gamma_{tm}\varepsilon x_{tm} - 0.30\varepsilon_{Pr}\varepsilon x_{tm} \quad (5)$$

OY = Oil Yield (%),

mc = moisture content of sandbox seed, γ_{tp} = roasting temperature,
γ_{tm} = roasting time, ε_{Pr} = expression pressure and εx_{tm} = extraction time

The corresponding statistical parameters of Eq. 5 are as shown in the Quadratic column of (Tab. 2). The positive and negatives signs in (Eq. 5) denote proportional and inverse relationship respectively between the succeeding quantity and the oil yield. Values in column "Prob > F" in (Tab. 3) with of less than 0.05 represents significant model parameters; in this case $ϒ_{tm}$, $εx_{tm}$, mc^2, $ϒ_{tm}^2$, $ε_{Pr}^2$, and $εx_{tm}^2$.

Table 3. ANOVA for Response Surface Quadratic Model of the Oil Extraction

Source	Sum of squares	DF	Mean square	F value	Prob > F
Model	1241.52	20	62.08	4.49	0.0069[s]
mc	58.56	1	58.56	4.23	0.0642
$ϒ_{tp}$	0.022	1	0.022	0.0016	0.9688
$ϒ_{tm}$	151.76	1	151.76	10.97	0.0069[s]
$ε_{pr}$	5.82	1	5.82	0.42	0.5299
$ε_{tm}$	568.13	1	568.13	41.06	0.0001[s]
mc^2	106.76	1	106.76	7.47	0.0180[s]
$ϒ_{tm}^2$	103.43	1	103.43	7.47	0.0194[s]
$ε_{pr}^2$	171.01	1	171.01	12.36	0.0048[s]
$ε_{tm}^2$	98.39	1	98.39	7.11	0.0219[s]
Residue	152.21	11	13.84		
Lack of fit	149.68	6	24.95	49.25	0.0003[s]
Pure Error	2.53	5	0.51		
Cor Total	1393.74	31			

With a high coefficient of determination (R^2 = 0.8908) (Tab. 2) and very low probability value of (<0.0001) as shown in Table 4, the model was concluded to be significant. The 0.89 value of the R^2 indicates high correlation between the process variables and sandbox oil yield. This infers 89.08% assurance of the model to explain 89.08% all the inconsistency relating the response.

Table 4. Test of between-subjects effect of process conditions on oil yield from sandbox seed

Source	df	Mean Square	F	Significance
Corrected Model	27	51.439	86.003	0.0001[s]
Intercept	1	10656.051	17816.504	0.0001[s]
mc	3	67.567	112.970	0.0001[s]
$ϒ_{tp}$	2	4.189	7.004	0.049
$ϒ_{tm}$	2	122.883	205.456	0.0001[s]
$ε_{Pr}$	2	124.977	208.957	0.0001[s]
$εx_{tm}$	2	164.746	275.449	0.0001[s]
Error	4	0.598		
Total	32			
Corrected Total	31			

The quadratic model showed a significant relationship between the oil yield and all processing parameters except roasting temperature. This means that any value of the roasting temperature range selected can be suitable during oil expression from sandbox seeds. The Model's F-value of 4.49 (Table 3) is an indication that the model successfully interpreted the interactions among the process factors and oil yield.

The quadratic relationship indicates that there exist optimum values of the process parameters considered above which oil yield begins to drop. This conforms to findings by [4] for mechanical oil expression.

CONCLUSIONS

From the range of process variables evaluated in this work, sandbox oil yield greatly increased at (4.0-8.0%) moisture content; (80.0-90.0^{o}C) roasting temperature; (5.0-15.0%) roasting time; (15.0-20.0 MPa) expression pressure; and (6.0-8.0 min) extraction time. The oil yield ranged from 16.38-38.68%. The maximum oil yield of 38.68% was obtained at the processing conditions of 6% wb moisture content, 85^{o}C roasting temperature, 15 min roasting time, 20 MPa expression pressure and 8 min pressing time. The process variables influenced the oil yield. The coefficient of determination, R^2 of 0.8908 of a mathematical model relating sandbox oil yield and process factors was an indication of excellent correlation between the independent process variable. From the levels of processing factors evaluated, the model preferred, sufficiently predicted oil yield from sandbox seed by mechanical expression.

REFERENCES

[1] Adewuyi A., Paul O., Awolade, P.O., and Oderinde R.A. 2014. *Hura crepitans* seed oil: an alternative feedstock for biodiesel production. *Journal of Fuels*, 464590 (8).
[2] Ajibola, O.O., Adetunji, S.O, and Owolarafe, O.K. 2000. Oil point pressure of sesame seed. *Ife J. of Technology*, 9(2), 57-62.
[3] Allen, T.F. 2000. *Hura crepitan* L. *The Encyclopedia of Pure Material Medical. HomeopatheInternational*, New Delhi, India, pp. 1-2.
[4] Bamgboye, A.I., and Adejumo, O.I. 2011. Effects of processing parameters of roselle seed on its oil yield. *Intl. J of Agric & Biol Eng*, 4(1), 82-86.
[5] Basumatary, S. 2013. Non-conventional seed oils as potential feedstocks for future biodiesel industries: *A Review Res. J. of Chem. Sciences*, Vol. 3(5), pp. 99-103.
[6] Bockisch, M. 1998. *Fats and Oils Handbook. Manuals by AOCS Press*.
[7] Box, G.P.E., Hunter, W.G., Hunter, J.S., 1978. Statistics for Experiments. *John Wileyand Sons Inc, New York*, pp. 335-375.
[8] Fakayode, O. A. and Ajav, E. A. 2016. Process optimization of mechanical oil expression from Moringa(Moringa oleifera) seeds. *Industrial Crops and Products* 90, 142-151.
[9] Feldkamp, S. 2006. Modern Biology. *United States: Holt, Rinehart, and Winston.* p. 618.
[10] Fowomola, M. A. and Akindahunsi, A. A. 2007. Nutritional quality of sandbox tree (Hura crepitans Linn.). *J. of Medicinal Food*, vol. 10, no. 1, pp. 159-164.
[11] Giwa, A., Bello, A. and Giwa, S.O. 2013. Artificial Neural Network Modeling of a Reactive Distillation Process for Biodiesel Production, *Intl. Journal of Sc. & Eng. Research*, 6(1): pp. 1175-1191.

[12] Hammonds, T.W., Harris, R.V., and Head, S.W. 1991. The influence of moisture content on the extraction of oil from fresh grated Coconut. *Tropical Sci.*, 31, 73-81.
[13] Idowu, D.O., Abegunrin, T.P., Ola, F.A., Adediran, A.A., and Olaniran, J.A. 2012. Measurement of some engineering properties of sandbox seeds (*Hura crepitans*). *Agric. and Bio. J. of North America*, 3(8), 318-325.
[14] Kagwacie, O.C., and Anozie, N.A., 1995. Effect of processing conditions on solvent extraction of oil from rubber seeds. *J. Agric. Technol*. 3 (1), 31-40.
[15] Khan, L.M., Hanna, M.A., 1983. Expression of oil from oilseeds – a review. *J. Agric. Eng. Res.* 28, 495-503.
[16] Matthäus B. 2012. Oil technology. S.K. Gupta (ed.), *Tech. Innovations in Major World Oil Crops*, Vol. 2.
[17] Mwithiga, G., and Moriasi, L. 2007. A study of yield characteristics during mechanical oil extraction of preheated and ground soybeans. *J. of Applied Sci. Res.*, 3(10), 1146-1151.
[18] Nwanorh, K.O. 2015. Extraction and characterization of oil from *Hura crepitans* (sandbox tree). *Intl. Res. J. of Edu. and Innovation (IRJEI)*, Vol. 1, No 5.
[19] Okolie P.N., Uaboi-Egbenni P.O., and Ajekwene A.E. 2012. Extraction and quality evaluation of sandbox tree seed (*Hura crepitan*). *Oil World J. of Agric. Sci.*, 8(4), pp. 359-365.
[20] Olaniyan, A.M. and Oje, K. 2007. Development of mechanical expression rig for dry extraction of shea butter from shea kernel. *J. of Food Sci. and Tech.*, 44(5), 465-470.
[21] Olatidoye, O.P., Adeleke, A.E. Adegbite, S.A. and Sobowale, S.S. 2010. Chemical composition and nutritional evaluation of sandbox (hura crepitan) seed flour for domestic consumption and industrial. *J. Med Appl. Biosciences*, Vol. 2, pp.72-83.
[22] Orhevba, B.A., Chukwu, O., Osunde, Z.D., and, Ogwuagwu, V. 2013. Influence of moisture content on the yield of mechanically expressed neem seed kernel oil. *Academic Res. Intl.*, Vol 4; No. 5.
[23] Ottih, O.P., Aneke, N.A.G., and Ejikeme, P.C. 2015. Production and characterization of paint driers from sand box seed oil (*Hura Crepitans*). *Intl. J. of Innovative Sci., Eng. and Tech.*, 2 (2).
[24] Shonekan F.O and Ajayi J.O. 2015. The biochemical analysis of *Hura crepitans* (Sandbox Tree) seed oil and meal. *Globalacademicgroup.com*, accessed January 15, 2016.
[25] Sivala, K., Bhole, N.G., Mukherjee, R.K. 1991. Effect of moisture on rice bran oilexpression. *J. Agric. Eng. Res*. 50, pp. 81-91.
[26] Southwell, K.H., and Harris, R.V. 1992. Extraction of oil from oilseeds using the hot water flotation method. *Tropical Science*, 82, pp. 251-256.
[27] Ward, J.A. 1976. Processing high oil content seeds in continuous screw press. *J. of American Oil Chemist Society*, 53, pp. 261-264.

EFEKTI PROMENE VARIJABLI OBRADE ULJA IZ SEMENA Sendbox (*Hura crepitans* Linn.): MEHANIČKO IZDVAJANJE

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Sažetak. Troškovi metoda ekstrakcije ulja učinili su mehaničku ekspresiju ulja poželjnom alternativom. Izvršeno je ispitivanje uticaja obrade promenljivih parametara na mehaničku izdvajanje ulja semena Sendbox (*Hura crepitans* Linn.).

Eksperimentalni dizajn korišćen za ovu studiju ima 5^2 Centralnu kompozitnu rotabilnu površinsku dizajn metodologiju .

Eksperimentalni faktori koji su uzeti u obzir bili su: sadržaj vlage, temperatura, i vreme zagrevanja, pritisak izlaganja i vreme ekspresije. Dizajn metodologije površinske reakcije usvojen za eksperiment je $\alpha_{0.05}$.

Najveći prinos ulja semena Sendbox (*Hura crepitans* Linn.), povećan je, i kretao se u rasponu od 16,38 do 38,68% kod sadržaja vlage od 4,0 do 8,0%; temperature zagrevanja od 80,0 do 100,0^{o}C; vremena zagrevanja od 5,0 do 15,0 min; pritiska izdvajanja od 15,0 do 20,0 MPa , za vreme ekstrakcije od 6.0 do 8.0 min. Maksimalni prinos ulja od 38,68% je dobijen u uslovima prerade kod 6% sadržaja vlage semena, temperature zagrevanja 85^{o}C, sa 15 minuta zagrevanja i ekspresijskog pritiska od 20 MPa, i 8 minuta izdvajanja ili presovanja.

Razvijen je model jednačine koja povezuje promenljive procesa sa prinosom ulja. Koeficijent determinacije (R^2) , koji se odnosi na ovaj process, bio je 0,8908.

Rezultati pokazuju da sadržaj vlage, vreme zagrevanja, pritisak izdvajanja i vreme ekspresije imaju značajan uticaj na prinos ulja semena Sendbox (*Hura crepitans* Linn.).

Rezultati dobijeni u ovoj studiji mogu poslužiti za dizajn procesa i opreme za ekstrakciju ulja iz semenki Senbox i drugih semenki ulja i orašastih plodova.

Ključne reči*: Sendbox seme* (*Hura crepitans* Linn.), *prerada, ekspresija, ekstrakcija ulja.*

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