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RESEARCH ARTICLE

DESIGN AND PERFORMANCE EVALUATION OF A KLUIKLUI EXTRUDER

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ABSTRACT

The shaping of kluiklui is the only unit step that has never been mechanized in the peanut processing into kluiklui. In order to reduce difficult working, the development of an extruder of kluiklui has been made. The method used combines functional analysis, product design, testing equipment, performance evaluation and sensory test. Materials in contact with the food product are made in stainless steel materials and wood that are adapted to food. The tests have shown that the equipment gave a better performance compared to the traditional process: equipment's flow rate is 60.32 kg/h against 10 kg/h obtained with the conventional process and the productivity is 95.5% against 87.3% with the conventional process. These results indicated a significant difference ($p<0,05$) between the technical performances of the two processes (Equipment and conventional process). Analysis of the composition of the kluiklui and the sensorial test carried out showed that there is no difference between the kluiklui obtained from the Equipment and those of the conventional process ($p> 0,05$).

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INTRODUCTION

The groundnut, *Arachis hypogaea*, also known as the peanut, is one of major agricultural crops in Benin. Today it is an important oilseed and food crop [1]. It is rich in oil and protein and has a high-energy value [2]. It is grown in more than 100 countries covering more than 26.4 million hectares with an average productivity of 1.4 tons per hectare [3]. Developing countries hold 97% of cultivated areas and 94 % of the overall production of this crop [4]. The first producers' countries are China and India with more than 60 % of the world global production [5]. The African continent, with its 10 million hectares of peanut cultivated areas and its 10 million tons, ranks second ahead of the American continent. Africa supplies about 25 % of the production mainly Nigeria, Senegal and Sudan and although second continent in terms of production of peanut, has the lowest yields per hectare (1 t/ha), compared to America (3 t/ha) and Asia (1.8 t/ha) [3]. Peanut production is very low in West African countries such as Benin. So, in spite of the increase in the peanuts cultivated areas from 2000 to 2012 (from 80,000 to 100,000 ha), in Benin, yields remain very low (600 to 800 kg.ha-1) [5]. In all sub-Saharan Africa countries kernels are used for oil extraction, cake named kluiklui, food and as an ingredient in confectionery products.

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Kluiklui are snacks made from peanut dough that is partially hydrated and de-oiled, and which is then shaped and fried [6]. This traditional food is extremely popular in Benin and is a source of income for the women who produce it. Kluiklui is a local product with high geocultural identity [7]. In Benin, the peanut sector for a long time has been a dominant sector. Unfortunately, in years 80-90, it downfell due to the competitiveness to the competition of oils (Palm, cotton, soy, etc.) industrially produced in large-scale [8] and on the other hand the aflatoxin contamination [9]. Despite this disturbance, peanut oil is the most favorite in the Beninese cuisine due to its aroma and its organoleptic properties and the production of the kluiklui is still a thriving business.

Unfortunately, if most of the unit steps are mechanized in the chain of the peanut processing, the production of the kluiklui phase is not mechanized. In order to try to improve the conventional technology, screw presses (manual press with vertical screw, hydraulic press and expeller) have been introduced. But it is clear that these attempts were unable to achieve a satisfactory result. Indeed, these types of technology exert a strong pressure on the product, 60 to 120 bars for manual screw presses and hydraulic presses and more than 150 bars for expellers, leading to obtaining a crab de-oiled whose use for the preparation of the kluiklui requires additional and tough work: milling, re-hydration and puddling. The process of kluiklui production starts with the cake from the oil extraction which is a partially de-oiled paste.

a b

Figure 1. Traditional method of preparation of kluiklui(a) Shaping of partially de-oiled peanut dough sticksand (b) cooking of shaped sticks

This dough is rolled into sticks on a wooden table (not always reserved for this) with hands (Fig. 1a). This practice is not only a consumer of labor but also from the hygienic point of view does not guarantee a healthy food quality of the kluiklui (dust in the environment, sweat are often from the transformer, etc.). The sticks are afterwards fried in oil for 20 to 25 minutes at a temperature of (90-110) ° C (Fig. 1b). After cooking, the kluiklui obtained are of medium size: [180-250] mm of length and [8-13] mm of diameter with sharp tips shaped cone. The form of the kluiklui stick is the most widespread form in Benin. However, they are sometimes produced in the form of flat cakes in the North (Djougou town) and in the form of circle or snails [8] in the Southeast in the Mono. Around the country, the kluiklui is an inexpensive source of protein, fat, minerals and vitamins constituting the population's food [10]. The preservation's tests of the kluiklui carried out by Garba and al [7] showed that the kluiklui will keep fairly well for nine months period. In order to help women who transform to get mechanized facility for the shaping of the kluiklui, this research has been initiated. The present research aims to improve the peanuts processing into kluiklui snacks in order to reduce difficult working in the process and preserve sanitary qualities of the product.

Specifcally, the research was intended to:

- define functions required of kluiklui extruding equipment;
- define principles used to satisfy functional requirements;
- analyse design ;
- develop a kluiklui extruding equipment ;
- Evaluate the performances of developed extruder.

MATERIALS AND METHODS

Materials

Vegetable Material : Partially deoiled peanut paste: The vegetable material utilized is the partially deoiled peanut paste. It is obtained after the oil extraction. Previous studies [6] have shown that the production of the kluiklui is only possible when the cake obtained from the extraction of peanut contains a residual oil rated higher than 8%. Indeed, the seed of peanuts contains between 45 and 50% oil ([11],[12]). That's the reason why the oil is extracted with presses of type expeller which extraction's rate is 40-43%, the cake cannot be used for the preparation of the kluiklui.

Materials Selection and Machine Description

Construction materials were selected based on their availability, durability, cost and corrosion resistant properties. Steel, Stainless steel and Teak (Tectona grandis) are the main materials used in the manufacture. The component parts of the equipment are: the cylinder, screw, nut and lower plate (Figure 4).

Methods

The method used for the design and development of the kluiklui extruding equipment includes the following steps: functional analysis, Design analysis, manufacturing and Equipment testing.

Functional analysis

Functional analysis ([13], [14]) is an method used in engineering design, which consists to search for and characterize the features offered by a product to satisfy the user's needs." The philosophy of the method is to abandon any idea of solution during the phase of analysis of the problem [15]. The Functional analysis is developed into two phases: the external functional analysis also called functional analysis of the need and internal functional analysis or technical functional analysis. The functional analysis of the need used in design product process (Value Analysis [13], Product Design ([16]–[18]), Design to cost [19]) allows to express the expectations in terms of service. It is an approach which consists in search, order, characterize, prioritize and/or enhance functions

(according to the NF X 50-150, ''actions of a product or one of its constituents expressed exclusively in terms of purpose'). It means to consider the system as a black box that is exclusively defined by its action (effects), and not by its content. According to Delafolie [20], the functional analysis is to identify a need in the form of service features that express the relationship between the product and its environment. The Functional Specification (FS) presents this modeling of the need in the form of a list of service functions expressing the relationships of the equipment to its environment. These functions are expressed exclusively in terms of purpose, in other words independently of any solution allowing them to be performed. Functions are defined in terms of assessment criteria and levels. Levels are not indicated in the list of service functions presented below (summarized in Table 1). The functional analysis System Technique ([21], [22]) is an internal action to the product (between its constituents) defined by the innovator, as part of a solution to ensure service functions. The functional block diagram applied to technical functions (Functional Analysis System technic, FAST) allows to present

Table 1. Functional Specification for kluiklui extruding equipment

	Function		Assessment criterion	Level
	The equipment must …			
F1	extrude the partially deoiled paste into sticks	C11	Flow rate	40 kg/h
		C12	Efficiency	95%
		C13	Final product quality	Traditional, no foreign bodies
		C14	Length	[180-250] mm
		C15	Diameter	[8-13] mm
F2	enable the operator to load the partially deoiled paste	C21	Loading height	0.55 m above ground
		C22	Storage capacity	12,5 kg
F3	Mix the seasoning with the partially deoiled paste	C31	Homogeneity	No lumps
F4	allow the operator to ensure easy maintenance	C41	Standard tools	Mechanical keys
		C42	Required level skill	worker level
		C43	Duration of cleaning	
F5	be fixable by the repairman at an affordable cost for the user	C51	components available	
		C52	Tools available	
F6	be profitable for the company	C61	Purchase price of the equipment	specify depending on equipment performance
		C62	Ability to auto financing	-
		C63	Volume of production per day C64	3 bags = 120 x 3 = 360 measures = 288 kg
		C64	Cost	*500 F CFA*
F7	Reproducible by local manufacturers	C71	Manufacturing operations mastered by the manufacturer	
F8	Use available energies	C81	Level of power available	Manual or Motor driven, but easy to start, not like a mill motor
F9	Enable the operator to adjust the kluiklui diameter in relation to peanut cost	C91	Modification of the extrusion diameter	
F10	enable the operator to sample the paste for spiciness			

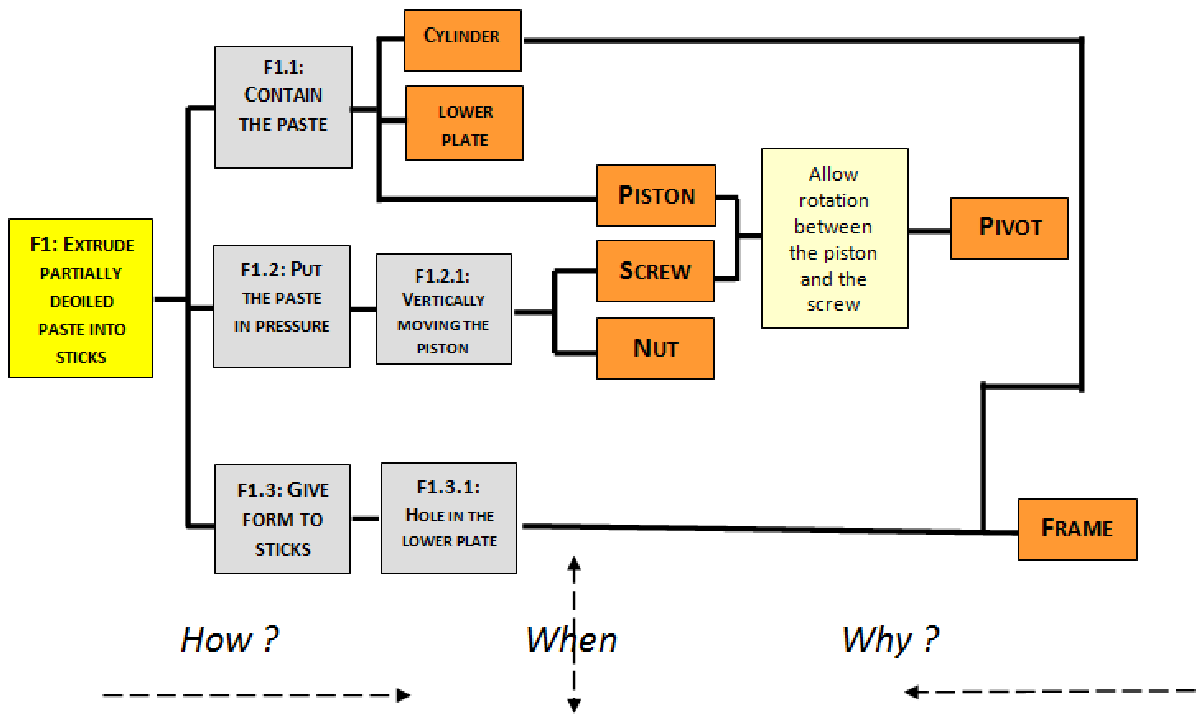

Figure 2. Functional Block Diagram for kluiklui extruding equipment

the solution adopted by viewing the functional logic of the system with its environment and the relationship between the principles. The Figure 2 presents Functional flow block diagram developed for kluiklui extruding equipment. The functional flow block diagram kluiklui extruding equipment is developed from main service function, F1 (rectangle colored in yellow in Figure 1). This is an external function to the system. This function is expanded, through the interrogation "How?" in three technical functions that are "Contain the paste", "Put the paste in pressure" and "Give form to sticks" (rectangle colored in ash in figure 1). F1.1 and F1.2 F1.3 functions are internal technical features to the system. The answer to the interrogation "How?" of the technical function F1.1 gave two solutions "Cylinder" and "lower plate" (rectangle colored in orange in Figure 1). They are entities of surface of the system. First, the development of the technical function F1.2 gave a technical function F1.2.1 "Pacific moving the piston" and then four solutions "Piston", "Screw", "Nut" and "Pivot". Finally, the function F1.3 gave a technical function F1.3.1 "Hole in the flat" and a "Frame" solution.

Design of the Lower plate

The lower plate reinforcement of stainless steel sheet was chosen so that it can withstand the stress due to the pressure available on the piston's face (300 kPa). It was perforated at the base with holes 8 to allow for kluiklui extrude to drain out. The maximum stress of mild steel is 400 MPa [24]. This is greater than the stress on the lower plate; the choice is therefore appropriate. Consider the lower plate reinforcement as a circular-shaped flat plate; the diameter is Ø 200 mm and a thickness of 12 mm.

Design of the Piston

For hygienic reasons and food compatibility, the teak (Tectona grandis) was chosen. Teak (Tectona *grandis*) in the N_3 strength group of timbers (grade 80 %) was chosen for the piston due to its adequate strength and durability. Its specifications [25] are: compression parallel = 11.2 $N.mm^{-2}$; E = 9500 $N.mm^{-2}$ and density = 640 kg/m3 (at 18 % moisture content) ([26]-[27]).

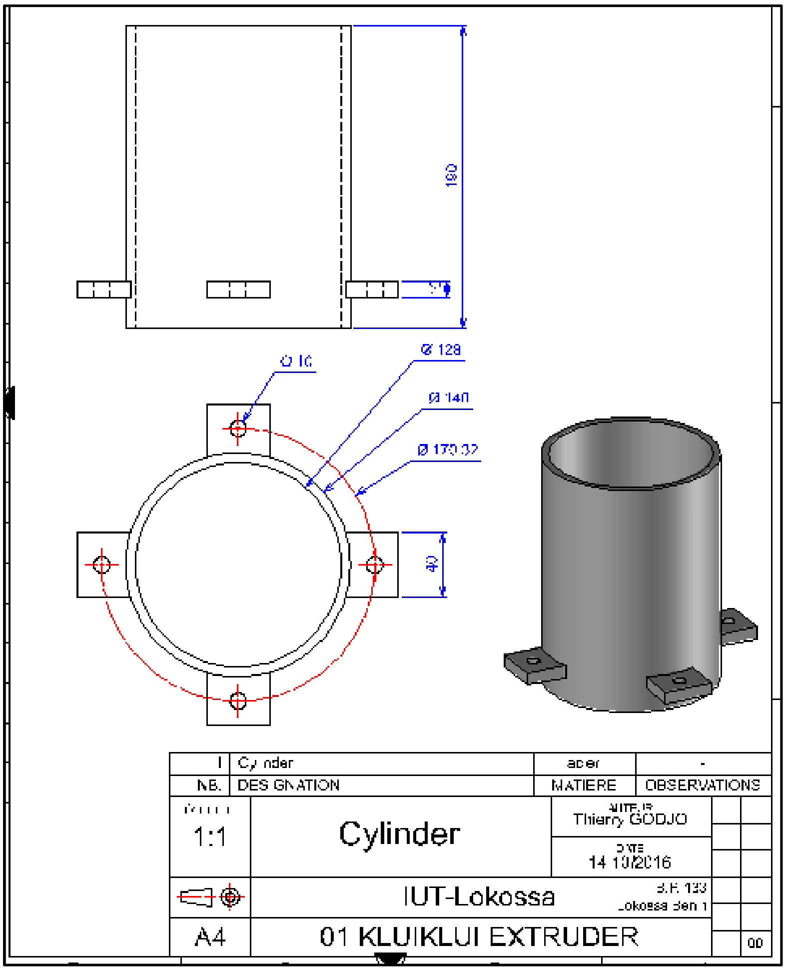

Figure 3. Cylinder Definition Drawing

Design analysis

Design of the Cylinder: The cylinder was designed to accommodate the allowable volume of paste per charge. It was fabricated from a 10 mm stainless steel sheet to 128 mm diameter, and 190 mm length. The volume of the cylinder was 2.44 x 10^{-3} m^3; therefore, according to the formula of steel sheet mechanical properties [23], its weight was calculated as 30.04 N. The dimensions of the cylinder are shown in Figure 3.

The fully assembled Kluiklui Extruding Equipment designed and fabricated is shown in Figure 4.

Principle of operation of the Kluiklui Extruder

The partially puporting peanut dough introduced in the cylinder is pressed (300kPa) using the piston moved the screw. The dough is extruded through 8 holes and kluiklui sticks are recovered as shown in Figure 5. The kluiklui shaped are collected and then cut with a knife to get the length of kluiklui between 180-250 mm).

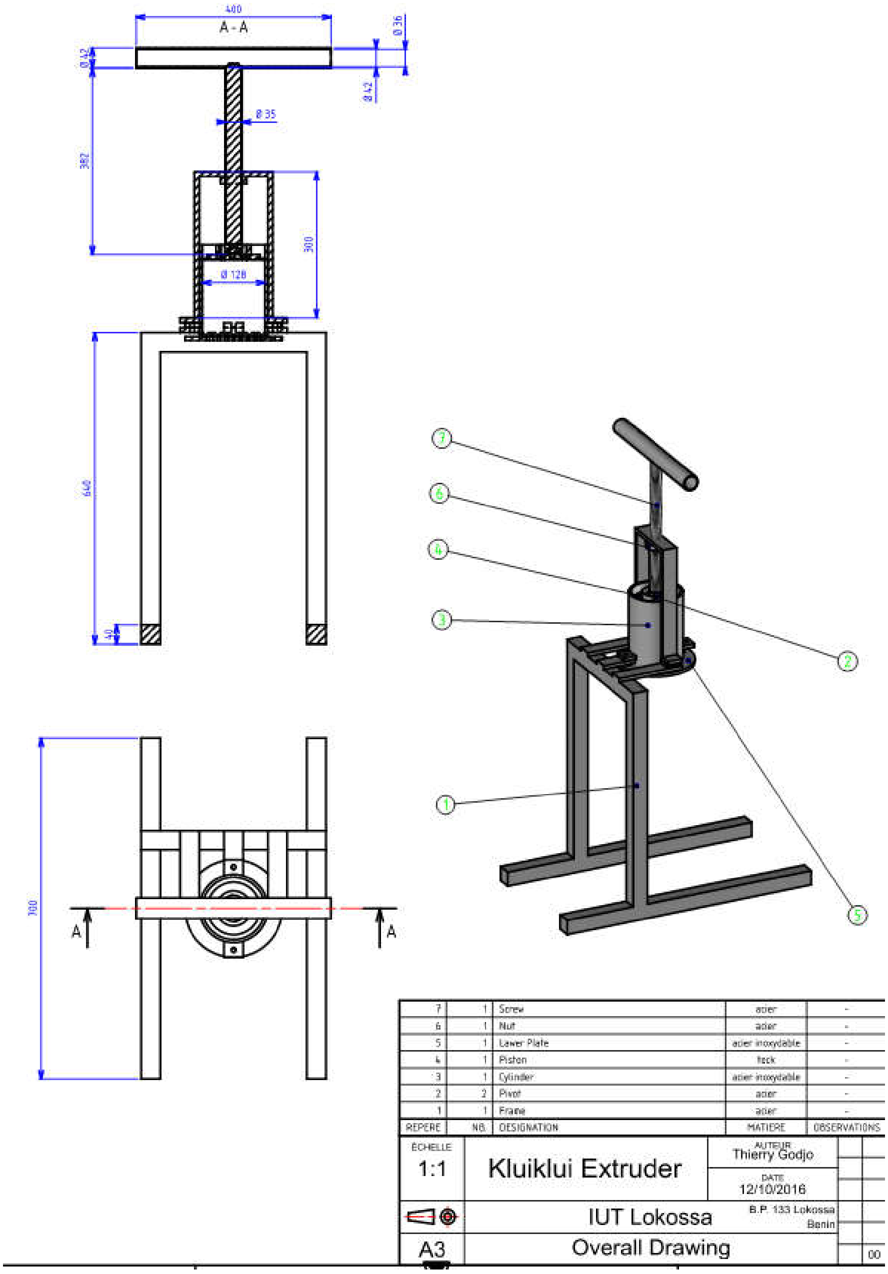

Figure 4. Overall Drawing of Kluiklui Extruding Equipment

Figure 5. Kluiklui ExtruderPrototypetested by a User

Testing and performance evaluation

The kluiklui extruder designed was tested and its performance was evaluated by the extruding efficiency, and Flow rate. The results of the test are presented in Table 2.

The extruding efficiency was evaluated by:

$$Extruding\,efficiency = \frac{\sum average \quad weight \quad stick\ kluiklui}{Total \quad Weight \quad of \quad \text{partially deoiled paste}\ introduced} \times 100\%$$

The Flow rate was evaluated by:

$$Flow\,rate = \frac{\text{Total amount of partially deoiled paste used}}{\text{Number of hours of extrusion}}$$

Sensory assessment indices

A sensory evaluation was conducted from tests of references. Two samples of kluiklui, obtained from the equipment and other traditional process were tasted by 10 consumers who gave their opinions over the color, the taste, aroma, crispness and the acceptability of two samples of kluiklui.

Statistical analysis

Statistical analyses conducted for this study were realized with Minitab software. The means and standard deviation flow rate and efficiency of the equipment and the traditional process were calculated and compared. Analyses of variance were also performed to firstly determine the differences between the variables flow rate and efficiency of the two processes namely equipment and the traditional method. The tests were conducted on four sites which are Cotonou, Cove, Ouessè and Banikoara. It is four agro-ecological zones of peanut's production in Benin. There are also places where peanut's transformation into kluiklui is mainly done. In total 40 tests were conducted on the facility and 40 other trials were conducted on the formatting of the kluiklui with the traditional process.

RESULTS

In Table 2, are presented the characteristics, the technical performance of the extruder of kluiklui compared to the traditional process.

Analysis of Structural Characteristics and Energy

Equipment's congestion (0.70 m x 0.38 m x1.22 m) meets the requirements of function 2 (Assesment criterion C21) of the Functional Specifications defined during design process and validated by end-users. Indeed, the loading height (1.55 m) desired by users has been taken into account in the equipment design process and manufacturing. Taking into account, this requirement allows a better work condition and thus an ergonomic gain. The energy used by the facility is human

Table 1. Characteristics and technical performances

		Extruder Equipment	Conventional Process
Structural characteristics and energy	Overall dimensions	0.70 m x 0.38 m x1.22 m	*Not applicable*
	Loading height	1.22 m above ground	*Not applicable*
	Storage capacity (kg)	12	*Not applicable*
	Energy used	Manually operated	Manually operated
Technical Performances	Flow rate(kg/hours)	N Mean StDev	N Mean StDev
		40 60.320 1.266	40 10.044 1.483
	Efficiency (%)	N Mean StDev	N Mean StDev
		40 95.500 0.682	40 87.300 6.198
Final product	Quality	Traditional	Traditional
	Average Length (mm)	[150-250]	[150-250]
	Average Diameter (mm)	8± 5.508	7.5± 0.050

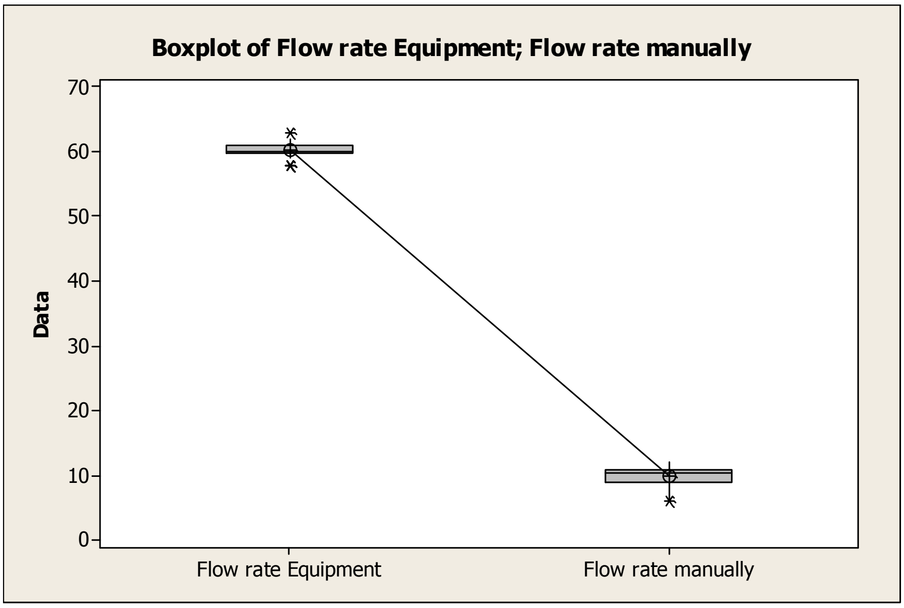

Figure 6. Analysis of variance of performances of two processes

energy, which meets the function F8 of the Functional Specifications.

Analysis of Technical Performances

The descriptive analysis of the equipment's flow rate and that of traditional process (Table 2) shows the following: the total number of tests is 40 for two processes: Equipment and Traditional process. The average flow rate of the equipment is equal to 60, 32 with a standard deviation equal to 1.27. As for the traditional process, the average is equal to 10.04 with a deviation type of 1.43. As for efficiency, average for the equipment is 95,500 with 0.682 as against 87,300 for the traditional process with 6,198 as standard deviation standard deviation.

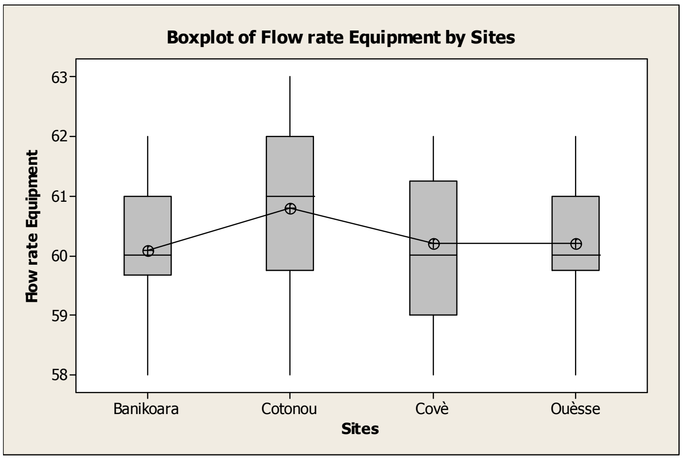

Figure 7. One way Analysis of variance Flow rate with factor sites

Analysis of variance of the means of the flows of the two processes gave a p value = 0,000. This p-value is less than 0.095 and as shown in the boxplotin Figure 6, there is therefore a significant difference between the means of the equipment and the traditional process flow. Obviously, the flow of equipment is 6 times the flow of the traditional process. There is a significant difference. It is a gain in time and volume of production. The gain in time allows the transformers to do other activities but this allows especially the reduction in the toughness of the work. The gain in volume of production caused the increase in income, so the increase in income and hence poverty reduction. Analysis of variance of the average of the flow of equipment compared to the test (Figure 7 below) sites showed no significant difference between the averages of flow between sites (p-value = 0.613).

Analysis of moisture and fat of the kluiklui

The descriptive analysis of the composition of the kluiklui (in this case the rate of moisture and Fat) made by equipment and traditional method is presented in the table 3.

Table 2. Composition of water, oil, and no-oil solid of the kluiklui

Variable Process	N	MeanStDev
Water Equipment	3	14.6670.577
Traditional	3	17.5000.250
OilEquipment	3	10.3670.551
Traditional	3	1.,4000.361
Non-oil solid Equipment	3	64.6670.208
Traditional	3	64.1000.260

It is observed that the water content's average of the kluiklui shaping by equipment (14.667%) is lower than that obtained with the traditional process (17.500%). This deviation is certainly due to the friction in the mechanism screw-nut that could create a warm-up. Also, the average content in oil of the kluiklui shaping by equipment (10.367%) is lower than that obtained with the traditional process (18.400%). Indeed, the pressure made by the screw on bottom plate extracted oil from the dough. In the traditional process, there is not this oil extraction. Furthermore, the pressure could also justify a reduction of the water content.

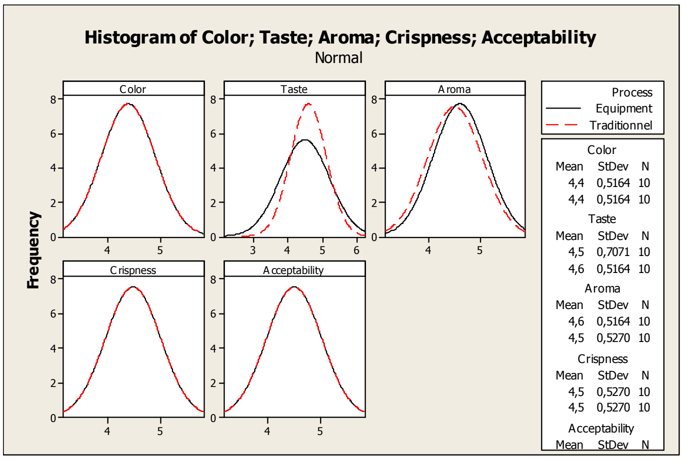

Figure 7. Histogram sensory test

Sensory test and evaluation of the Kluiklui

The Histogram sensory test of variables color, taste, flavor, crispness and acceptability show that averages don't differ at all (except for taste) and the distribution of the data is the same. Compared analysis of variance between the process for each of variable shows the p value is practically equal to 1 so there is no significant difference for sensory test of the kluiklui of the two different processes.

Conclusion

In this article, shaping of the kluiklui equipment has been designed, manufactured and tested. This is a technological innovation because this operation has never been mechanized. Tests have shown that the designed equipment is technically more efficient than the traditional process (equipment 60,320 flow kg/h against 10.44 kg/h for the traditional process). This shows that the use of the equipment increases the volume of production contributing to the increase in the income of the famers and in turn contributes to the reduction of poverty. Beyond the results and design response to a latent need in food processing sector (lack of appropriate facility capable to reduce the toughness of the kluiklui formatting work), this article has shown how to express the expectations of users in functions (that must assume the future facility) and meet the needs of users by the development of equipment.

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