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ECO-DESIGN OF CASSAVA PRESS IN AGRIFOOD MANUFACTURING IN AFRICA

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ABSTRACT

Gari is cassava flour widely used in West Africa, more specifically in Benin. The transformation of cassava into Gari involves several stages. The pressing step is one of the steps to remove hydrocyanic acid from the pulp, multiply microorganisms and help increase the palatability of Gari. Pressing equipment is made of metals which negatively impact the environment because their welding requires energy consumption and generates waste (toxic gases, electrode residues and iron filings). This study is undertaken with the aim of minimizing the negative environmental impacts due to the manufacture of presses. To achieve this, we used the IBS method "Innovation for Breaking and Sustainability" to eco-design the press. The implementation consists in analyzing and evaluating the negative environmental impacts of the press. The work made it possible to design and to produce on the one hand two prototypes of cassava press and on the other hand to make their comparison. The first press produced is conventional, that is to say of steel materials whose pressing system is single-pitch screw. The second, called eco designed press, is made of wood material with a variable pitch pressing system. The results of the tests made it possible to obtain characteristics such as: Total mass 90.417 kg, Manufacturing time 08h 27min 08sec, Electric energy consumed for manufacturing 17.8 kWh, Efficiency 12.9537 ± 0.6427 (kg/h), Performance 6547 ± 86.6516 (sec), Extraction rate 0.2718 ± 0309 for the conventional press and Total mass 51.05 kg, Manufacturing time 12h 21min 10s, Electric energy consumed for manufacturing 16.04 kWh; Efficiency 18.0710 ± 0.3342 (k /h), Performance 4692.5 ± 212.8291 (sec), Extraction rate 0.3326 ± 0.0072, for the eco-designed press. The results showed that the eco-designed press generates fewer pollutants and consumes less electrical energy and fewer materials. It is almost half the weight, 1.5 times more profitable and 28% more efficient. So we generate less waste.

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INTRODUCTION

The essence of technologies helping to improve environmental performance has evolved in recent decades. In addition, several technologies result from the nature of eco-design technologies. Among other things, incremental innovations, one of the eco-design strategies, are the most adapted to the southern country (Romeiro, 2014). Incremental innovations are improvements to equipment or manufacturing techniques that occur continuously over the history of techniques. Most innovation strategies, added and integrated, have so far belonged to the category of incremental innovations, in the sense that they only constitute improvements in quality, productivity, the diversity of the production process which settle down over time (Faucheux, 2006). Numerous attempts at technical innovations in the transformation of agricultural equipment in West Africa have proved unsuccessful, but these failures have nonetheless helped to evolve the approaches and methods of designing equipment (Ferré, 2018).

The IBS method "Innovation for Breaking and Sustainability" is developed in the context of integrating the concepts of sustainable development in the design of agricultural equipment in southern countries, especially Benin. It makes it possible to choose and assess the environmental aspects of food processing equipment based on the "NF E 01 - 005" standard and other design methods such as "CESAM and D4S" (Hounsounou, 2019). Among other things, the IBS method makes it possible to develop its offer to limit resource requirements and reduce waste. It is also a proactive approach to register over time. Furthermore, in Benin, agriculture occupies around 75% of the active population and constitutes the most important sector of activity in the economy (Ministère de l'agriculture de l'élevage et de la pèche, 2017). But it is variously practiced and faces several problems. The business sub-sectors: design and manufacture of agro-equipment that drives agriculture remains in a poorly developed state. Most of the equipment is conventionally designed and manufactured using accessible materials

(Dédéhou, 2015). Classic food processing machines consume a lot of energy and do not meet the challenges of sustainable development (Hounsounou, 2019). Furthermore, Gari is a transformation of cassava. It is obtained from grated, pressed and roasted cassava and is the main traditional cassava processing product in Benin. Over 50% of national cassava production is transformed into Gari each year (Biaou, 1998). The machine used during the pressing process is the press. It is important in the manufacturing process of Gari. Does the press comply with environmental standards?

With a view to answering this question, it is important to make a quantitative assessment of the negative environmental impacts generated by this agro-equipment. This environmental analysis is necessary to make the process of transforming cassava into Gari clean. The pressing step of the cassava pulp is one of the steps that allow evacuating hydrocyanic acid, to multiply micro-organisms and to contribute to the increase in palatability of Gari. Pressing equipment is made of metals which negatively impact the environment and whose welding requires energy consumption and generates waste. This study is undertaken with the aim of minimizing the negative environmental impacts due to the manufacture of presses. For this, a comparative analysis from an environmental point of view, of two prototype presses previously designed and manufactured will be carried out. One of the prototypes will be classic and the second will be eco-designed.

MATERIALS AND METHODS

Material

The equipment used for the experimentation within the framework of this study is divided into three categories: Plant material, manufacturing material and characterization material.

- Manufacturing equipment: It includes the welding station, electrode rods, the electric drill and the electric lathe.
- Plant material: These are peeled and grated cassava.
- Characterization equipment: it consists of two conventional and eco-designed cassava presses, digital weighing, electric energy meter, stopwatch, camera, dynamometer, and data sheets recording the characteristics of the two presses.

The two presses made it possible to compare yields, performance, humidity, pressing time, masses, manufacturing time and electrical energy consumed for manufacturing. As for the other devices:

Digital scale: It was used to know the mass of each component of the presses. Therefore, the mass of press.

Electric meter: It was used to evaluate the amount of energy consumed by the manufacturing phase of the presses.

Chronometer: It made it possible to assess the working time of each phase of operation.

Dynamometer: It was used to use the same pressing torque for the two presses.

Registration cards: They allow the parameters of each of the two presses to be saved.

Electric lathe: It was used to make the single screw with constant pitch of the conventional press and the variable pitch of the eco-designed press.

Electric drill: It was used to perforate the opposite pressing plate. Welding machine and electrode rods: They made it possible to weld material against each other.

Methods

Firstly we proceeded by collecting data and information from direct observations, semi-structured interviews and documentary analyzes. Secondly we identified the equipment manufacturers for the manufacture of the two types of presses under the same working conditions. Finally we proceeded to characterize the agricultural equipment and compare it from a technical, environmental and economic point of view. Furthermore, the surveys were carried out in the 12 departments of Benin in order to really know the techniques of design and manufacture of cassava pulp presses. Once the conventional manufacturing techniques are known, we proposed the integration of the IBS method in the design and manufacture of agricultural equipment. Then we explained the interest of the IBS method to the challenges of sustainable development to equipment manufacturers. A group of equipment manufacturers has been identified to traditionally manufacture the press and implement the IBS method in order to manufacture the eco-designed press. The classic press is designed and manufactured with metallic materials. The pressing system of the conventional press is a single screw system. As for the eco-designed press, the pressing system is variable pitch and allows increasing the clamping pressure even more without using much force.

Implementation process for the IBS method: The IBS method has three (03) essential axes for the implementation. The first axis and the second axis deal with the study of the criteria for implementing the method, the objectives of the equipment manufacturers and the choice of equipment to be eco-designed. In our context, we designed a team of two manufacturers, an eco-designer and a user. Furthermore, the objectives of the equipment manufacturers are oriented towards environmental issues and making savings on the equipment manufactured. The choice to design the cassava pulp press comes from the identification of the most designed equipment in Benin as well as information from the field. The third axis consists in prioritizing the environmental aspects, choosing the guidelines and repackaging the initial equipment with the notions of incremental innovation. The development of the Innovation for Breaking and Sustainability (IBS) method is carried out in the document (Hounsounou, 2019).

Characterization procedure for classic and eco-designed presses

We used the same setup technique for both presses. The configuration process is divided into three phases:

The first phase consists of measuring the mass of each press piece. This phase makes it possible to determine the total mass of each of the presses. The second phase consists of measuring the electrical energy consumed and the time taken to assemble the parts for each press. This phase makes it possible to determine the consumption of electrical energy and the overall manufacturing time of each press. The third phase consists in locating a manufacturer of Gari and in carrying out the configuration operations under real working conditions. During this third phase we got closer to the manufacturer of Gari in Kétou in the department of the plateau in Benin. The manufacturer of Gari allowed us to have access to the cassava pulp samples and to work in real conditions. We took four samples of cassava pulp which we bagged and weighed. Then we used the dynamometer to have the same torque of clamping forces for each of the presses. Finally, when we noticed that the water no longer came out of the sample bag of pressed cassava pulp, using the stopwatch, we measured the duration of pressing of pressed cassava pulp. Photos 1, 2 and 3 below show these operations.

Photo 1. Measurement of the screw rod and wiring of the electric meter

Photo 2. Bagging and weighing of cassava pulp

Photo 3. Pressing the cassava pulp with the two types of press

RESULTS AND DISCUSSIONS

Design and manufacture of cassava presses: After study, we obtained two prototype presses shown in Figure 1 and 2. Figure 1 shows the classic conceptual press and the eco-designed conceptual press. Figure 2 shows the conventional press manufactured and the eco designed press manufactured. The manufactured presses made it possible to analyze the environmental impacts linked to the raw materials and manufacturing stages. Figures 1 and 2 below illustrate the two conceptual and manufactured presses.

Determination of the total mass of cassava presses: Each press has a set of elements divided into three parts: the pressing screw device, the support and the plates. Tables 1 and 2 below indicate the mass of each of the elements of the presses manufactured as well as their total mass.

Table 1. Elements-Mass-Materials of the classic press

Phase	Various components	Mass (kg)	Materials
Press screw device	screw	8,795	drawn steel
	nut	3,84	drawn steel
	bearing	0,24	steel
	pressure plate	10,55	steel
Support	UPN 80	34,58	steel
	UPN140	9,56	ferrous alloy
	profil in L to 14	2,254	steel
	sheet-metal 15	3,02	steel
uplands	cover	0,283	steel
	perforated tray	13,27	steel
	recovery box	4,025	steel
Total		**90,417**	steel + ferrous alloy

Table 2. Elements-Mass-Materials of the eco designed press

Phase	Various components	Mass (kg)	Materials
Pressing screw device	Screw	9.755	Drawn steel
	Crank		
	Mobile Nut	0.375	Drawn steel
	Fixed Nut	8.540	Drawn steel
	crossing		
	Bolts of 10	0.225	Steel
	Bolts of 12	0.580	Steel
	Pressing cylinder	0.500	Steel
	Pressure plate	3.320	teak wood
Support	Vertical and horizontal supports	27.755	teak wood
Total		**51.05**	Wood and steel mixture

Determination of the manufacturing time and energy consumed by the conventional press and the eco designed press: Table 3 below shows the overall manufacturing time and the overall electrical energy consumed by each phase constituting the conventional press and the eco-designed press.

Table 3. Manufacturing time and energy consumed by presses

Phase	Classic press		Eco design press	
	Manufacturing Time	Electrical energy consumed	Manufacturing Time	Electrical energy consumed
Pressing device	03 h 02 min 59 sec	10.8	05 h 26 min 56 sec	15.9
Support	02 h 43 min 33 sec	3.9	06 h 54 min 14 sec	0.5
Uplands	02 h 40 min 36 sec	3.2		
Total	**08 h 27 min 08 sec**	**17.9**	**12 h 21 min 10 sec**	**16.4**

Table 4. Characterization of the presses

Press	**Classic**					
Test	1	2	3	4	Standard deviation	Average
Aqueous mass (kg)	25,5	24,2	23,08	21,51		
Anhydrous mass (kg)	18,86	18,48	16,86	16,28		
Performance (h ou s)	6678	6569	6489	6452	**86,6516**	**6547**
	1,855	1,8247	1,8025	1,7922	**0,024**	**1,8186**
Efficiency	13,7466	13,2622	12,8044	12,0018	**0,6427**	**12,9537**
Extraction rate (%)	0,2603	0,2363	0,2694	0,3212	**0,0309**	**0,2718**
Press	**Eco design**					
Test	1	2	3	4	Standard deviation	Average
Aqueous mass (kg)	25,5	24,2	23,08	21,51		
Anhydrous mass (kg)	17,12	16,33	15,13	14,36		
Performance (h ou s)	4941	4797	4668	4364	**212,8291**	**4692,5**
	1,3725	1,3325	1,2966	1,2122	**0,0591**	**1,3034**
Efficiency	18,5792	18,1613	17,7994	17,7442	**0,3342**	**18,071**
Extraction rate (%)	0,3286	0,3252	0,3444	0,3324	**0,0072**	**0,3326**

Table 5. Features of the presses

	Efficiency (Kg/h)	Performance (sec)	Extraction rate (%)	Appreciability		
				Mass Rate (mp2/mp1)	Profitability (TFp2/TFp1)	Efficiency Rate (Ep2-Ep1)/Ep2
Classic press	12,9537 ± 0,6427	6547 ± 86,6516	0,2718 ± 0,0309	1.77	1.5	28%
Eco design press	18,0710 ± 0,3342	4692,5 ± 212,8291	0,3326 ± 0,0072			

Test and validation ofClassic and eco-designed presses: The tests made it possible to obtain the performance, the yield and the extraction rate of the conventional press and the eco-designed press indicated in table 5. As for Table 4, it summarizes the different values obtained in the four (04) pressing test steps as well as the standard deviation value, the average value and the extraction rate calculated. Table 5 indicates through the appreciability, mass rate, la profitability and the efficiency rate of the eco design press by the conventional press.The majority of its constituent materials are easily recyclable materials (wood). The eco-designed press has a better yield, performance and extraction rate than that of the conventional press. In addition, the conventional press is made of recyclable steel materials but requires enormous resources for its reintroduction into a production line. Likewise, its reuse requires expenditure, especially since it is made of steel, a non-renewable raw material. The variable pitch screw system made it possible to exert months of force using the eco designed press which optimizes the pressing time. Figure 3 below provides an overview of the materials used, the energy consumed and the waste produced during the production of the eco-designed press. The guidelines show that the mass of the eco-designed press has been reduced, waste and electrode residue minimized. Indeed, Figure 3 shows the results of the production of the eco-designed press. First, in order to improve the new eco-designed equipment, a variable pitch screw system has been integrated in place of the simple screw system. Then as far as the material is concerned, wood is used instead of steel.

Table 6. Monitoring of guidelines

Explored tracks	Predictable gains	Environmental aspects Concerned	Monitoring indicators
Use of wood instead of steel	Easily recyclable materials	Raw Material (Wood)	- 39,367 kg of Wood Moreover
	Elimination of welding operation	Manufacturing (Energy, waste)	- 4 kWh - 0,448 kg of Electrode residue
	Elimination of polishing and drilling operation	Manufacturing(Energy, waste)	- 3,1 kWh
Integration of variable pitch system	Operation addition of screw-nut	Manufacturing (Energy, waste)	+ 5,49 kWh + 0,375 kg
	Suppression of operation of the arm horns of the crank	Manufacturing (Energy) Raw Material (Steel)	- 1,2 kg

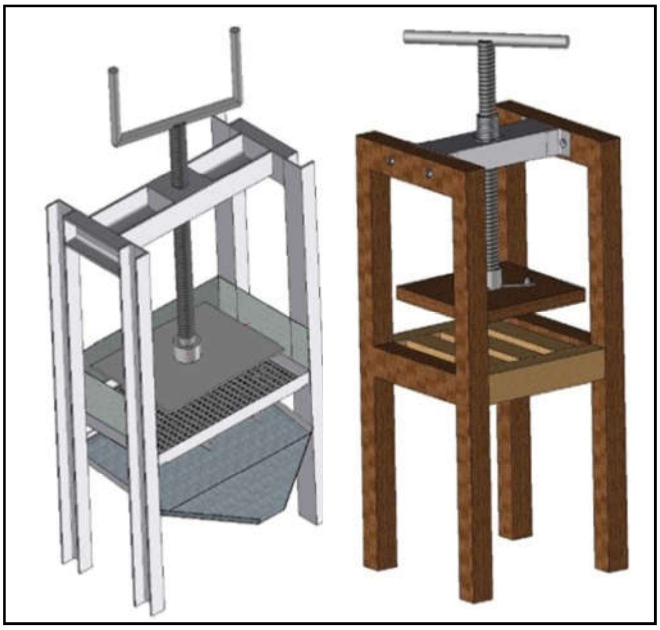

Figure 1. Conceptual press

Figure 2. Manufactured press

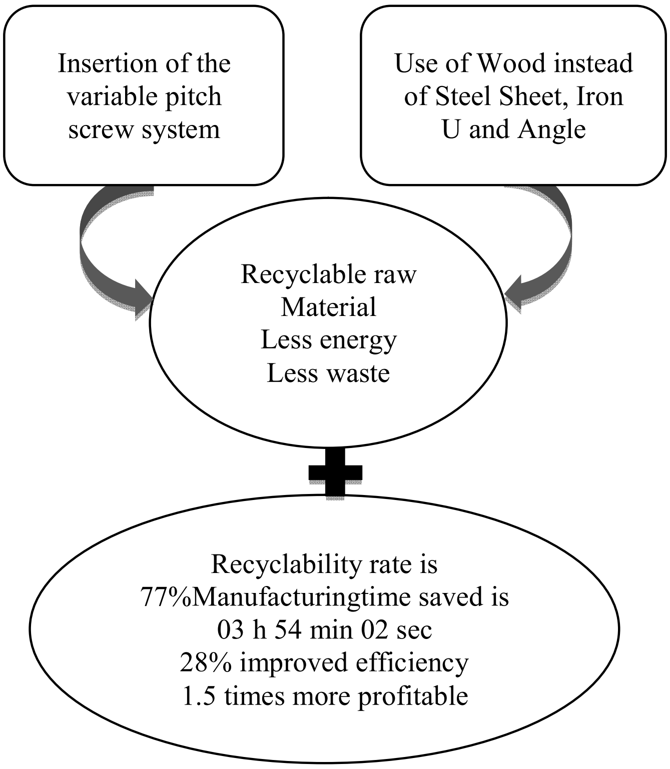

Figure 3. Manufacturing balance of the eco-designed press

In addition, the new eco-designed press has a manufacturing time of less than 03 h 54 min 02 sec than the conventional press. Finally, the new press has generated less waste, less electrical energy. The eco design press is made with recyclable raw material and has a 28% improved efficiency and 1.5 times more profitable.

Conclusion

The new eco-designed press is manufactured on the basis of the Innovation for Breaking and Sustainability (IBS) method which is a participative and multidisciplinary approach which meets the real needs of manufacturers of food processing equipment. The results linked to the tests in real working conditions and to the validation made it possible to better appreciate the eco-designed press compared to the traditional press. The weight is worth approximately 2 times, the profitability 1.5 times and the efficiency 28% times. Test and validation work with other Gari manufacturers will continue with the goal of having a final model that will be widely used. In addition, the monitoring indicators in Table 6 indicate the environmental aspects that had a negative impact during the manufacturing process of the eco designed press. These are Raw Materials and Manufacturing. Similarly, they clearly indicate the amount of raw material recycled 39.367 kg, the amount of energy saved about 1.61kWh despite the integration of the variable pitch screw system which requires 5.49 kWh of energy.

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