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IMPLEMENTATION OF CLEAN PRODUCTION IN CUPS AND DISHES WITH COFFEE GROUNDS*

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Abstract

In this paper, a methodology for the sustainable creation of MDF-type products based on coffee beans is presented. This type of production must be profitable, sustainable, and environmentally friendly. Therefore, the relationship between the biomass content and drying temperature of the medium density chipboard plates and the physical characteristics that have low time and constant drying pressure is determined. For this purpose, an experiment is carried out to determine the relationship between biomass at different levels of binders in a percentage way concerning coffee grounds, in specimens of size already determined for experimentation. This process makes it possible to determine possible differences in levels of similarity for a wooden MDF pattern.

Keywords: coffee grounds, clean production, coffee plates, medium density fireboard, sustainability.

1. Introduction

The purpose of this article is to present clearly and concisely one of the possible strategies to reduce the environmental impact of industrial production through the development of alternative products from the use of coffee grounds.

In Colombia, there are reports on the levels of coffee ground production, in which the abundance of this raw material is notorious. Nowadays, both in homes, as centers of mass concentration such as specialized coffees and especially in industrial processing plants (that is, instant coffee plants), are taking the coffee ground as a waste product. In Colombia, the

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use of coffee ground is based on compost or organic processes to fertilize the land, waste is sent to landfills or burned in boilers of mineral carbon.

As far as world coffee production is concerned, Colombia currently ranks third since it is leading in the export of this product thanks to the work of the producers. Because of the process of industrialization of coffee, only 5% is used in the realization of the beverage and the remaining 95% is already waste (ground coffee). For this reason, it is necessary to prevent and mitigate the impact of this production on the environment, it is important to create cleaner production proposals aimed to develop new valuable products. In this paper is an already known methodology to create MDF (wooden plates) is used. This process is developed through an extruder machine among other tools that serve in this production. When developing the formulation. In this sense, it was found that the lowest possible environmental impact was generated by seeking cleaner production alternatives.

In the development of the prototypes described in this paper, the processes that allow an ideal resistance for the finished product have been used. The material has been exposed to different processes of useful life such as different temperatures and relative humidity levels. In search of a point of environmental and productive equilibrium, various binders and methodologies have been used in the preparation of the final material, always thinking about the non-use of chemicals such as urea-formaldehyde.

2. Study Material

Coffee ground is a residue generated in the roasting of the soluble coffee and corresponds to the solids of the already roasted coffee bean. According to (Rodriguez Valencia and Zambrano Franco, 2013), it corresponds to 10% of the dry grain. This occurs during the steam extraction process that is carried out in the plants, in the same way, that is produced in the preparation of a roasted and ground coffee, either by french press, American, or any of the known extraction methods. Approximately 50% of the green coffee produced in the world is used in the production of instant coffee; for preparing a cup of coffee in homes as in markets such as Starbucks, the process of industrial extraction consists of a steam current system, obtaining an aqueous solution of approximately 20ºB (degrees Brix).

The waste that is generated in the extraction stage is classified as organic waste and seeks to provide a quick and low-cost final disposal in boilers for steam within the same plant and using it for biogas production and its use in boilers.

Like all vegetables, the coffee ground is composed of cellulose, proteins, lipids, minor elements, bases, nitrogen, and water, normally cellulose corresponds to 38%, lignin 27%, in other words, has a fiber content of up to 71% that facilitates the production of cellulose biopolymers, about 13% - 27% is incinerated without any use and the rest is sent to landfills, this despite the characteristics and chemical properties of degraded coffee powder that can be marketed (Gracía-Muñoz and Riaño-Luna, 1999).

The porosity of coffee borage particles has a structure similar to that of wood sawdust, as well as its cellulose content and caloric capacity so that when the particle is smaller, its water retention capacity is greater, this corresponds to particle sizes smaller than 600 microns and the particle sizes of the commercial the household are 2 mm in diameter and for instant coffee are greater than 2mm being the minimum acceptable size for extraction. Being a lignocellulosic material rich in sugar and have high levels of insoluble fiber, the coffee ground presents interesting properties for use in emulsions such as natural polymers, that is because its porosity and absorption capacity of oils and liquids generally give greater structural stability for industrial purposes use of the coffee erase.

It is important to mention that having the thermostable capacity in a wide temperature range if used in medium density plates, the coffee ground can provide environmental temperature control. The implementation of coffee ground in the industry presents great

challenges, to be used as an additive in the production of biopolymer cell fibro plates, clay-based coffee bricks for the construction of houses, and reduce by 20% the use of natural clay using weight ratios from 1 to 5. When burning them at temperatures of more than 900°c, it's possible to see that the coffee ground has the capacity to generate pores in the clay and to reduce its density and weight, improving the acoustic characteristics and generating lighter structures.

In (Eliche-Quesada et al., 2011), it can be observed that in the proportions of 3 to 5 % of coffee blot, where the bulk density shows a decrease concerning the pattern of 6%, the compression capacity improved, This research aims to obtain more than 30% erasure in the structure giving the possibility of having a different way of agglomerating cellulose that is already commonly known. It is intended a material based on the coffee ground. Coffee ground is considered a waste material, without any service other than compost for the cultivation of fungi (Marston, 2017) such as hazelnuts or organic fertilizer preparation, generated in soils and increase in the absorption of chemical bases such as potassium, sodium, magnesium, which are more easily absorbed by plants leaving the soil without nutrients, In the instant coffee process it is estimated that less than 5% of the biomass generated is used in the production of the drink, the waste of the extraction process in steam towers in counter-flow is expelled to the waste zone with a humidity of approximately 60% and send to landfills.

The coffee ground was supplied by coffee shops, which is a producer of several coffee beverages and the raw material to produce the prototypes used at this stage of the investigation. The coffee ground is a material of physicochemical characteristics like wood sawdust. One of the drinks that are generally consumed by society both in Colombia and in the world is coffee in its different presentations, both roasted and ground, and instant, generate large productions of coffee grounds.

This insoluble coffee ground particle can be used in different applications such as the production of bricks with natural clay or in the production of medium-density fireboard (MDF) for indoor application. The world's largest consumers of instant coffee are the United States and more than two plants are producing this product in the country.

For Colombia, both the production of MDF and instant coffee are part of the export businesses, both the consumption of instant products without chemicals such as instant coffee and the idea of recycling wood to avoid consumption of tropical forests improve the production of both products every day. Colombia is a small producer of instant coffee but has great potential to grow. Its grain has been made known in the European markets with the JUAN VALDEZ stores (Juan Valdez Café, 2020) but it must testify and improve the quality of production, reducing the carbon footprint. In this sense, the market requires new products that meet the characteristics of wood-based MDFs based on raw material using it as a by-product of coffee and not as insoluble waste.

It is important to consider that, the most limiting quality characteristic for the production of MDF is the residual urea-formaldehyde concentration in the plates. Therefore, it is necessary to carry out studies to know what levels of production can be obtained from the MDF based on the use of coffee borage in laboratories or coffee-producing areas to determine which variables condition the availability of the material, with binders and drying conditions in laboratory conditions allowing to identify the effect it generates on the variables used to determine the quality of material in its continuous and discrete characteristics. In order to make corrections in the binders for the fluff ratio in the biomass of the plates and determine if extrusion is necessary so that cracking or loss of dimensions is avoided during drying, a process will be applied under controlled pressure and time. fixed drying. By having different drying temperatures, the ideal drying temperature will be identified to continue the pressure and thus produce agglomerate plates of coffee beans as a by-product of instant coffee production. The coffee grounds have physicochemical

characteristics similar to those of wood sawdust, its similarity in size of particles and a cellulose level, allows a similar treatment in the creation of MDF with the difference that with coffee grounds you can choose to use binders other than those used by large producers who normally use Urea Formaldehyde base [6] which could be toxic or harmful to health.

The characteristics of this organic material allow it to generate links with natural binders for the creation of biomass, such as those used for the creation of clay and coffee-based bricks, to reduce costs and weight in the bricks. Given the high demand for instant coffee in the country and the export and expansion levels of national companies such as COLCAFE and DESCAFECOL in the world and local markets, it is possible to have continuous production of lees from coffee as waste or as a by-product in the production of instant coffee. For Colombia, it is a good opportunity to generate business and, therefore, the variables that influence its transformation into MDF and the marketing of this material as a finished product.

It is possible to create strategies that help to control the variables that intervene in the useful life and the physical characteristics that make products based on coffee grounds similar to products on the market. The above is possible with a job benchmarking or adjusting sources that contribute to deteriorating the quality of the products obtained, these problems include fracture errors, malleability, hardness, color, aroma, porosity, as well as possible fungi and insects.

3. Methodology

An experimental comparative research project is being carried out. It is presented by manipulating an experimental variable not tested, under rigorously controlled conditions, to describe how it affects a particular situation or event. (Tamayo y Tamayo, 2011). For the development of coffee ground agglomerates, it was carried out a research design with a quantitative approach, where a panel is used in scoring formats on scales 0-5 to compare the organoleptic characteristics. The samples will be subjected to a physical test to compare it to a wood standard.

The quantitative design will allow determining if the hypothesis is true and to have advances for a new investigation. Two types of boards will be produced according to the binders and each of these will be allowed to dry to the environment for 48 hours 3 of each, looking for a binder content of 40% 50% and 60% a type of roller pressing will be used for the removal of excess resin in another treatment looking for a suitable% resin. For this treatment, the agglomerate will be carried out with a temperature between 120 and 160 ° C and will be left with a constant pressure (Indrayani et al., 2014).

The measurable effects on the dependent variables are presented with the physical and mechanical analysis of the specimens. The internal validity is clearly reliable, preliminary tests have been carried out showing that the treatments mentioned are those that allow obtaining results for an evaluation of the process. Dependent and independent variables are controlled in the process to avoid unplanned variations. In the post-test, the mechanical and physical evaluation of the specimens is performed as can be seen in Table 1.

We worked with 46 experimental units that we will call the sample. Samples will be carried out to determine the physical and mechanical characteristics. As a procedure, three experimental units of each treatment has been selected. The type of sampling was completely random (simple random). Sampling and random distribution in drying ovens for the experimental process have been carried out systematically (stat graphics). The factors are % coffee bean biomass, % binder T1, % binder T2, a delta of temperatures. Finally, in Table 2 some statistical values are provided for MFD units.

Table 1. Variable control and manipulation

Variable / *Process*	*% Coffee Ground*	*Temperature*	*Pressure*	*Process Time*	*% Binder*
Variable manipulation	O	O	O	O	O
Variable control		O	O	O	

Table 2. Statistical values for MDF units.

Caliber	*Density (kg/m^3)*	*Humidity (%)*	*Elasticity (kg/cm$_2$)*	*Weight (kg)*	*Traction (Pounds)*
9	700	8±3	23.000	0.0966	6.0
12	690	8±3	23.000	0.1075	6.0
15	670	8±3	23.000	0.1111	5.5
18	670	8±3	23.000	0.1145	5.5
25	660	8±3	21.000	0.0747	5.0
30	660	8±3	21.000	0.0897	5.0

Fig. 1 demonstrates the visual appearance of these data

4. Results

In the laboratories of physical-chemical analysis of soils of the National University in Medellín-Colombia, was obtained that the physical-chemical analysis of the ground coffee, was identified a particle size of 2mm, a humidity of 83%, and a pH of 4.7; the eraser was dehydrated in a controlled manner in air recirculation stalls at an average temperature of 95 ° C until obtaining a final result of 6% humidity, the acidity was analyzed by taking a sample of dry erasure (5g.) (6% of moisture), by boiling 200 ml and allowing to stand at room temperature for acidity determination by color shift with phenolphthalein quantified with 1N grade sodium hydroxide. The statistical values for MDF units obtained for density, elasticity, weight, and traction can be seen in Fig. 1.

Among the tests performed, there is the absorption of water which consists of submerging the brick for 24 hours in water to have a final weight value and quantifying the absorption rate of the brick, this test was performed on the three prototypes. It will work with 2 levels in each of the factors. "Centimeters of crushing" is our response variable to find the percentage ratio of coffee bean biomass and binder T1 and binder T2, as can be seen in Fig. 2.

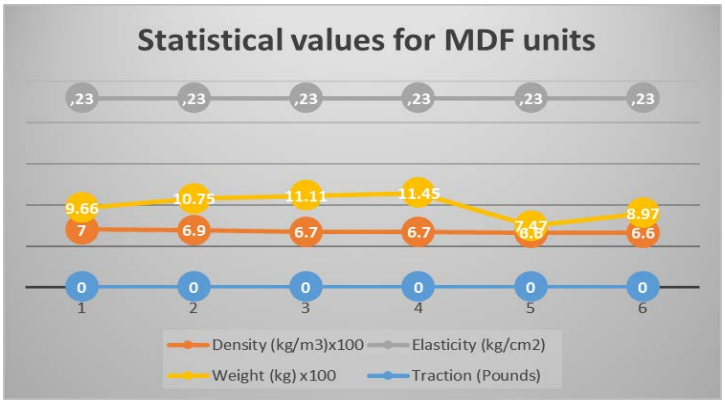
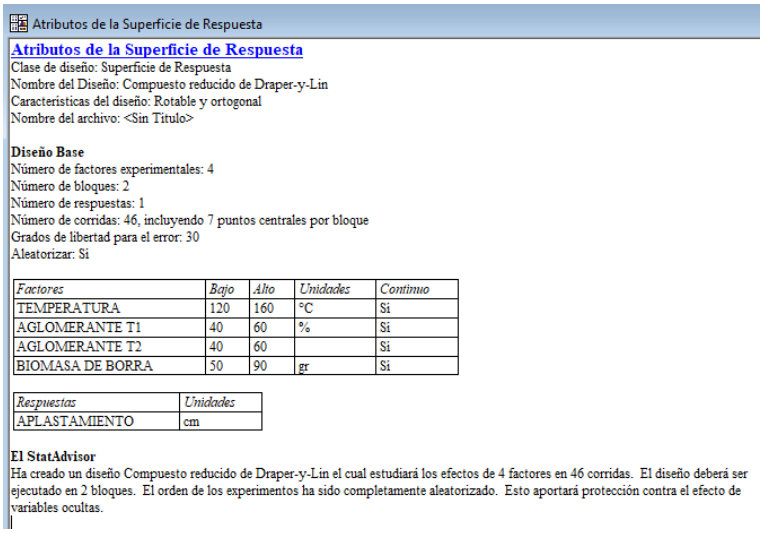


Fig.1. Visualization of the statistical values for MDF units.

In Fig. 3 it is possible to see the screening design along with the experimental factors and its different times.

The formula adaptation process has proven that temperature influences the drying of the MDF, we can work with the oven at that temperature, otherwise it will be worked with the lowest temperature. Two types of Colatan GTF and Colatan GT 10 adhesives in equal proportions have been used, with the corresponding % of coffee ground to satisfy the volume of the molds, dried to the environment, with three different unmolding times.

The density of the MDF is the objective of the test, a density of 1.0 gr/cm^3 with a measure of 20 cm ×10 cm×0.5 cm is taken as the basis of the response. In Fig. 4 it's possible to see the drying time in hours for all three blocks under study.



Atributos de la Superficie de Respuesta

Atributos de la Superficie de Respuesta

Clase de diseño: Superficie de Respuesta
Nombre del Diseño: Compuesto reducido de Draper-y-Lin
Características del diseño: Rotable y ortogonal
Nombre del archivo: <Sin Título>

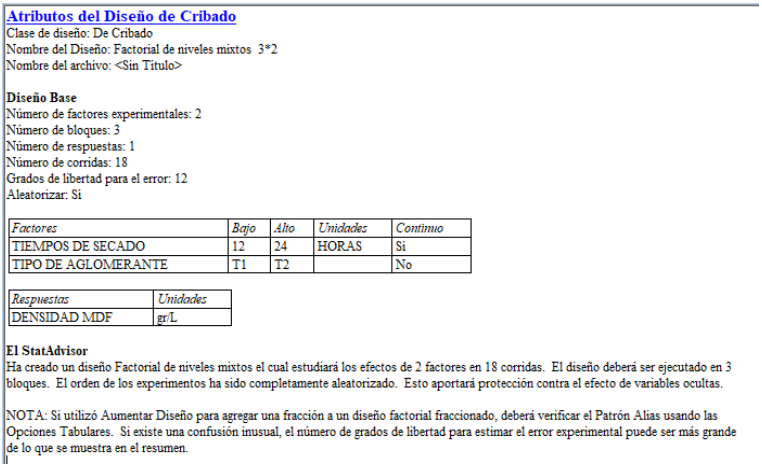
Diseño Base
Número de factores experimentales: 4
Número de bloques: 2
Número de respuestas: 1
Número de corridas: 46, incluyendo 7 puntos centrales por bloque
Grados de libertad para el error: 30
Aleatorizar: Si

Factores	*Bajo*	*Alto*	*Unidades*	*Continuo*
TEMPERATURA	120	160	°C	Si
AGLOMERANTE T1	40	60	%	Si
AGLOMERANTE T2	40	60		Si
BIOMASA DE BORRA	50	90	gr	Si

Respuestas	*Unidades*
APLASTAMIENTO	cm

El StatAdvisor
Ha creado un diseño Compuesto reducido de Draper-y-Lin el cual estudiará los efectos de 4 factores en 46 corridas. El diseño deberá ser ejecutado en 2 bloques. El orden de los experimentos ha sido completamente aleatorizado. Esto aportará protección contra el efecto de variables ocultas.

Fig. 2. Response surface attributes.



Atributos del Diseño de Cribado

Clase de diseño: De Cribado
Nombre del Diseño: Factorial de niveles mixtos 3*2
Nombre del archivo: <Sin Título>

Diseño Base
Número de factores experimentales: 2
Número de bloques: 3
Número de respuestas: 1
Número de corridas: 18
Grados de libertad para el error: 12
Aleatorizar: Si

Factores	*Bajo*	*Alto*	*Unidades*	*Continuo*
TIEMPOS DE SECADO	12	24	HORAS	Si
TIPO DE AGLOMERANTE	T1	T2		No

Respuestas	*Unidades*
DENSIDAD MDF	gr/L

El StatAdvisor
Ha creado un diseño Factorial de niveles mixtos el cual estudiará los efectos de 2 factores en 18 corridas. El diseño deberá ser ejecutado en 3 bloques. El orden de los experimentos ha sido completamente aleatorizado. Esto aportará protección contra el efecto de variables ocultas.

NOTA: Si utilizó Aumentar Diseño para agregar una fracción a un diseño factorial fraccionado, deberá verificar el Patrón Alias usando las Opciones Tabulares. Si existe una confusión inusual, el número de grados de libertad para estimar el error experimental puede ser más grande de lo que se muestra en el resumen.

Fig. 3. Attributes of the screen design

	BLOQUE	TIEMPOS DE HORAS	TIPO DE	DENSIDAD MDF gr/L
1	1	12,0	T2	
2	1	18,0	T2	
3	1	24,0	T2	
4	1	12,0	T1	
5	1	24,0	T1	
6	1	18,0	T1	
7	2	12,0	T2	
8	2	18,0	T2	
9	2	24,0	T2	
10	2	12,0	T1	
11	2	24,0	T1	
12	2	18,0	T1	
13	3	12,0	T2	
14	3	18,0	T2	
15	3	24,0	T2	
16	3	12,0	T1	
17	3	24,0	T1	
18	3	18,0	T1	
19				

Fig. 4. Drying time for all three blocks under study

With the results of the hypotheses, it is possible to determine working times and optimize the value of Z based on time and productivity, considering the restrictions obtained from the results of this experimental analysis of the MDF concerning the minimum times that each of the binders must have and its benefit for the cost of this. According to results and the initial time-binder treatment, two different types of boards will be produced according to the binders. They will be allowed to dry for N resulting hours, 3 of each following the formulation protocol (binder-biomass).

The materials are mixed by hand in a cylindrical container with a blade agitator until a homogeneous color is found in the mixture; the stirring time is estimated according to the previous results in minutes. It will be molded without a laboratory press and it will be replaced with Zinc boxes previously designed for this purpose with the standardized and previously mentioned measures. To prevent the material from sticking a pre-treatment with high temperature, we release the agent by removing it once finished drying. The initial weight, final weight, difference, and moisture acquired for water absorption evaluation in different materials can be seen in Table 3. The results obtained in Table 3 can be seen in Fig. 4, for the material number "3" especially is possible to see less moisture acquired.

The permeability of test sample number "3" shows greater efficiency and resembles the MDF control sample with 2.15% absorption. The two tests with lower permeability are subjected to density analysis and have great similarity giving greater clarity about the quality of the formulation as can be seen in Fig. 6.

Table 3. Water absorption (permeability)

Material	*Initial weight*	*Final weight*	*Difference*	*% Moisture acquired*
1	20.3	22.1	1.8	8.14%
1	20.5	22.4	1.9	8.48%
1	21	24.4	3.4	13.93%

2	33	36.1	3.1	8.59%
2	34.3	36.8	2.5	6.79%
2	35	38.8	3.8	9.79%
3	40	41.1	1.1	2.68%
3	40.5	41.6	1.1	2.64%
3	42	42.9	0.9	2.10%

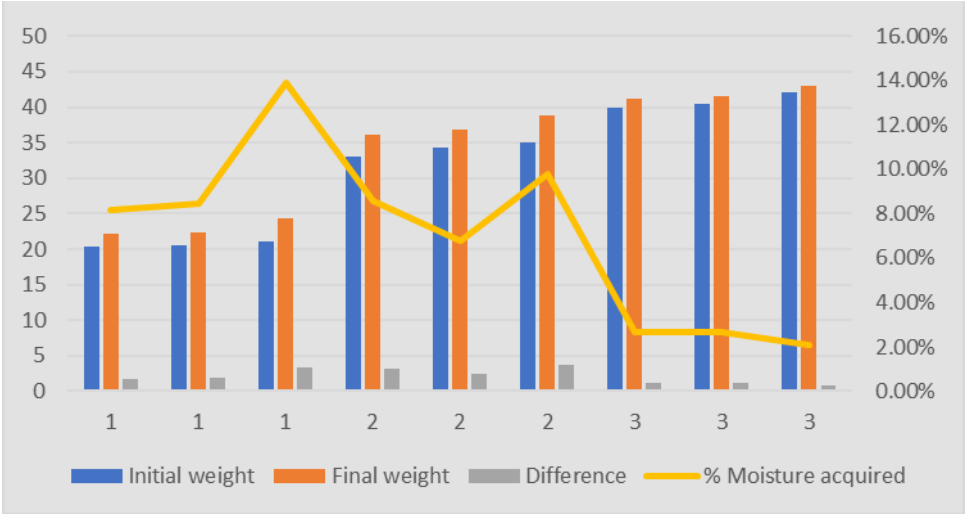


Fig.5. Water absorption of the samples

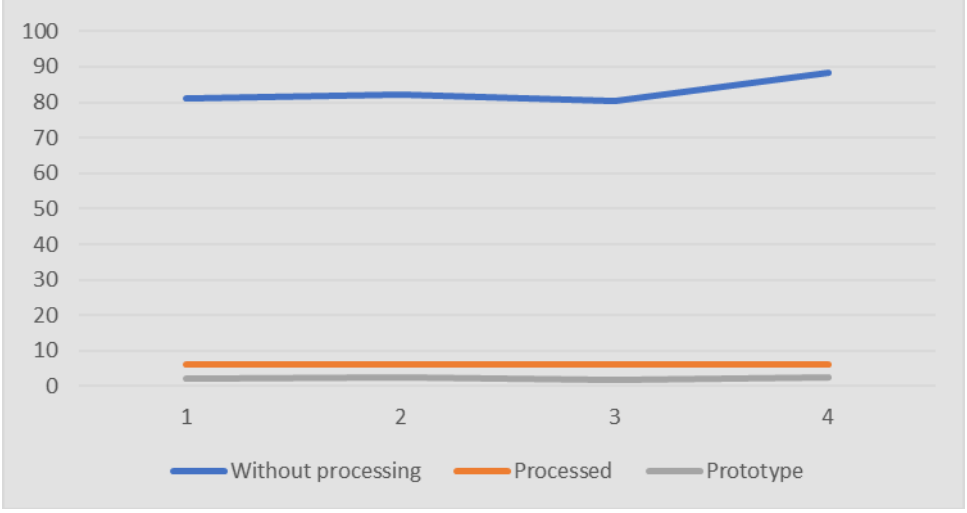


Fig.6. Comparison of the samples' humidity

The final humidity of the prototype allows a lifetime of 12 months. This lifetime is quite high for the final product. The elaboration of the process can be seen in Fig. 7. The process analyses the mixing and measure of humidity.

As a result of the process, it's possible to see a cup and dish in Fig. 8

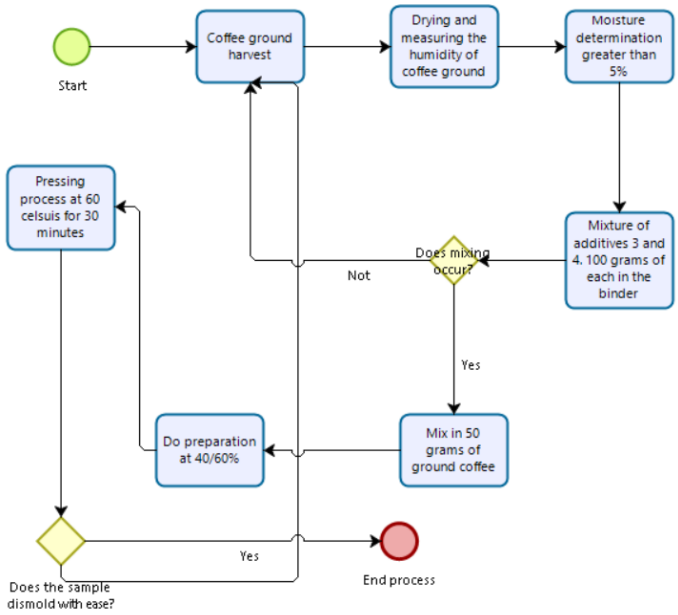


Fig. 4. Making coffee ground products. Description of the process

Fig. 8. Cup and dish as a result of the process.

5. Conclusions

The permeability of the samples from test 3 shows greater efficiency and resembles the MDF control sample with 2.15% absorption. The two tests with lower permeability depend on density analysis and have great similarity giving greater clarity about the quality of the formulation. The final humidity of the prototype allows a useful life of 12 months, it is still high for the final product. After performing the moisture and permeability analysis, the process can be continued. The permeability presented allows working with surfaces of 2 to 3 mm thick in the final products. It will begin with the molding of the products since the prototypes of the molds are already available.

It is possible to build a product development model based on coffee grounds. Through the process described here, it is possible to contribute to clean production and environmental sustainability (Bedoya-Corrales et al., 2018). For future research, it is proposed to attach between 10% and 15% wood sawdust to improve the physical characteristics of the product.

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