



Figure 1. Prototype of sustainable packaging. Source: La peruana coffee, 2019.

DEVELOPMENT OF SUSTAINABLE PACKAGING USING AGRICULTURAL RESIDUES SUCH AS RICE STRAW AND COFFEE PULP IN PERU

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The presented research paper investigates a socio-environmental project that consists of the development of a sustainable packaging, based on organic waste such as coffee and rice. Peru is a global rice and coffee producer, exporter, and distributor country. Therefore, it has a great supply of agricultural residues. In the case of coffee, a considerable amount of waste is generated such as the pulp, the shell, the breadth, and the fresh water; in the case of rice, the residues include the shell and the straw. Based on these materials, our packaging “La Peruana Coffee” will be marketed as a sustainable container for processed coffee, especially intended for coffee consumers in the city of Lima, Peru.

peruvian food system / agricultural residues / sustainable packaging / coffee pulp/
rice straw

Gr (%)	
Cell content	63.2
Neutral detergent fibre	36.8
Detergent acid fibre	34.5
Hemicellulose	2.3
Cellulose	17.5
Lignin	17.5
Lignified protein	3
Crude protein	10.1
Insoluble ashes	0.4

Table 1. Constituents of cellulose walls of coffee pulp. Source: INCAP 1978.

Coffee is the leading agricultural export product in Peru; moreover, Peruvian coffee is accounted as one of the ten most export products, following other assets as some minerals, oil, natural gas, and fishmeal (MINAGRI-INIA 2019). However, the agricultural, forest and agro-industrial residues of Peru—such as those of coffee and rice—are resources not currently exploited commercially (INIA 2019). Indeed, there is a lack of development of an innovation product based on these materials (INIA 2019), for which we approach proposing the development of a new sustainable packaging—“La Peruana Coffee”.

The coffee sector, indeed, as many others in the world, is highly affected by the cycle of plastic production, contamination, and waste management. Coffee is a ferociously in-demand product, and it takes a toll on the planet. Every year, as reported by National Geographic, approximately eight million tons of discarded plastic reaches the ocean from coastal countries. In addition, certain additives that usually increase materials performances in terms of strength, elasticity, and durability can extend the timeframe of wasted plastics to decompose (Parker 2019). For this reason, we consider that developing a new 100% biodegradable container to package coffee could contribute to reducing the environmental pollution generated by the use of plastic in the coffee sector.



Figure 2. Coffee pulp in the coffee production areas. Source: the Peruvian coffee, 2019.

THE FOOD PRODUCTION SYSTEM IN PERU

The food system builds on the concept of a 'system' in which there are attributes of the whole that the single elements do not own per se (FAO 2017, p. 4). In this sense, FAO (2017) defines the food system as made up of the integration and interdependence of various "elements", "activities" and "actors", enabling the cycles of production, processing, distribution, and consumption of food in a country. In Peru, agriculture mostly shows a low productivity or low market competitiveness of small farms (finca), as well as a high vulnerability to climatic fluctuation, with estimated losses of up to 15,000 ha per agricultural season (FAO 2010). In the production and distribution cycles of our country, it is argued that, after being harvested in the agricultural portions of the coast and the forest, food is transported for transformation and marketing in the city of Lima, where currently live 9,674,755 inhabitants of a total Peruvian population of more than 32 million inhabitants (INEI 2019).

The consumption of organic food in Peru has increased due to a local demand of healthy and genuine products, with no further transformation or added value. According to the group of producers Ecológica Perú, an increase of 70% has occurred in ten years. Evidence of this positive trend is given by the rising number of "bioferias"—especially in the city of Lima that counts seven of these organic mar-



Figure 3. Rice straw. Source: La Peruana Coffee, 2019.

kets—which provide local population with Peruvian produce free of pesticides and artificial fertilizers (Soto Fernández 2015).

With respect to coffee, there is 2% of internal coffee consumption that increased 66% in the last three years in Peru thanks to the opening of coffee shops in the country, mainly in Lima, as informed the Peruvian Ministry of Agriculture (Peru21 2012). Despite the greatest amount of it is exported to USA and Europe, the trend of domestic consumption is growing in the country, together with a demand for national production and the use of coffee residues.

Coffee in Peru

Peru ranks as the ninth coffee exporting country and the second exporter of organic coffee, following Mexico, worldwide. The socio-economic context surrounding its production is characterised by more than 200,000 farming families working in the sector and only 30% of producers belonging to some type of organisation. A third of agricultural employment is related to the coffee market and coffee plantations cover the 6% of the country's agricultural lands. (MINAGRI-INIA 2019)



Figure 4. Obtaining a prototype based on coffee pulp and coffee straw. Source: Peruvian coffee, 2019.

Rice in Peru

In the period 2001–17, an increase in the production of paddy rice occurred in the country at an annual rate of 2.4%, shifting from 2 million 28 thousand tons in 2001 to 3 million 39 thousand tons in 2017. A growing trend of rice production has been observed in this timeframe, with the exception of 2004, that registered only 1 million 845 thousand tons of rice. (MINAGRI–DGESEP 2018, p. 1) Such trend was driven by a double factor: an increasing harvested area (grew 2.0% average per year) and the increase in yield (grew 0.4% average per year). (MINAGRI–DGESEP 2018, p. 1)

AGRICULTURAL WASTE

Peru collects 16 Mt per year of waste derived from agricultural, agro-industrial, and logging activities. The province of Chiclayo (Lambayeque) has the highest amount of this waste (1.3 Mt per year). This province produces rice and sugar cane in significant volumes. The provinces of Ascope (La Libertad) and Santa (Ancash) are in a similar situation and produce more than 1 Mt per year of this waste. (FAO 2010) The agro-industrial coffee sector contributes to the total amount of agricultural waste: it produces, indeed, 2 Mt of annual coffee, whose residues are made up of pulp and

peel (FAO 2010). Coffee pulp has favourable fibres to make a type of paper, according to the research of Aguilar-Rivera et al. (2014), who did an experiment applying the physicochemical analysis used by the TAPPI (Technical Association of the Pulp and Paper Industry). With the objective of evaluating the quality of the coffee pulp for the manufacture of paper, the samples of the experiment gave favourable results to continue compressing with another fibre (Aguilar-Rivera et al. 2014).

Accumulation of coffee pulp is a widespread phenomenon in the country. Figure 2, for example, shows the mass of these residues in a farm, in the Peruvian jungle called "Paucarbambilla".

Residues from coffee processing in the extraction of the grain are discarded into the environment, causing contamination (INCAP 1978, pp. 19). Table 1 shows the chemical composition of the coffee pulp.

There are investigations of new products based on coffee pulp such as the production of organic fertiliser, protein extraction, and pulp for the extraction of molasses. Likewise, although this material has not been extensively investigated and currently does not have an immediate application to industry, it represents a viable alternative given its enormous organic potential (INCAP 1978, pp. 19).

Rice straw is easy to pulp as a paper fibre because of the open structure of the plant and its low lignin content compared to wood; chemical reactions are surface reactions. The thin cell walls of the straw present a large initial surface area for chemical attack and for the pulp. Rice straw is undoubtedly an agricultural residual potential to be used in innovations of new products according to its own characteristics (Saldivar Chea 2005). This indicates that it is a potential resource to develop paper or similar to cardboard.

MARKET INVESTIGATION

Currently there is a clear trend in the international arena to take ecology into account. The packaging of the products has become one of the factors that have long polluted the environment. Hence, aspects such as the possibility of recycling and the biodegradation of the packaging should be considered essential (Apaza Quispe 2014). Sustainable packaging is on the minds of all brands today due to the increasing pressure from consumers regarding eco consumption in all sectors. This leads brands to rethink the ecological credentials of their products and packs and, as we said in previous lines, the trend is already an urgency (Raconteur 2018). Among the recyclable packaging stands out that biodegradable, which disintegrates in less time than traditional plastic and is harmless to the environment. Another even

better option is that of compostable packaging, which can be integrated together with other waste to obtain compost. Likewise, the trend in 2020 for eco-packaging has become more fashionable than ever, not only in technologies, processes, and designs, but also in the need to use recycled and recyclable materials. (Solutions packaging 2018)

Sustainable packaging companies

- The Chilean company “Biogusto” employs rice husk, the waste deriving from the rice industry, as a raw material to develop biodegradable packaging. Thus, it offers a 100% natural, biodegradable, and recyclable product (biogusto.cl 2018).
- The startup “Ooho” has created a container made from seaweed extract that breaks down in a natural environment in six weeks, being it also edible. With this, it intends to combat the excessive use of plastic in single-format water bottles (Notpla.com 2020).
- The “Maracuyea” is a Peruvian venture that seeks to relate to Peruvian food and educate on issues of responsible consumption, local agriculture, and environmental responsibility. This undertaking is a healthy, delicious, and eco-friendly ice-cream, whose packaging is the passion fruit shell so that, when you finish eating it, all the residues are degradable. It boosts a process of raising awareness not only of nature, but also of the agricultural reality (Maracuyea 2020).

Packaging design for sustainability

Packaging concerns the containment, protection, handling, delivery, presentation, promotion, and use of products. It aims to create economic, social and environmental value (Varghese, Lewis, Fitzpatrick 2012). Strategies toward sustainable development, such as an increased efficiency, recyclability and elimination of toxic components, must be balanced against all relevant performance criteria during production, distribution, storage and use (Varghese, Lewis, Fitzpatrick 2012).

The idea of balancing, however, implies trade-offs. While this is often necessary, the aim should be to design and manufacture packaging that simultaneously delivers economic social and environmental value. This may require a departure from “business as usual” to find “win-win” solutions and new innovative ways of achieving the required objectives.

Designing for sustainability requires a commitment to rethink the design of the product-packaging system. There are potential points between objectives, for example:

- Material efficiency of a plastic pouch vs. the recyclability of a plastic bottle.
- Environmental benefits of enhanced recyclability vs. the cost of changing the packaging.
- Elimination of heavy metal-based inks or pigments vs. the marketing advantage of vibrant and durable colours. (Varghese, Lewis, Fitzpatrick 2012).

The use of sustainable resources such as agricultural residues greatly helps innovation and the creation of new products.

LA PERUANA COFFEE

Our project “La Peruana Coffee” consists of the development of a sustainable packaging based on the agricultural residues of the Peruvian production system of coffee and rice. In particular, rice straw and coffee-pulp have been employed in the design, as a high potential of use was found in their organic fibre components. The prototyped container (Fig. 4) is characterised by being entirely compostable due to a degradation period of approximately five months.

The main objective of the project is to generate social and environmental benefits for the community of Peruvian farmers and consumers, through an innovative product design strategy. Novel approaches to the design process should, indeed, begin by rethinking the agricultural waste problem in a more open and creative way. That is why we tackled the socio-ecological impact of local coffee and rice residues and, after investigating the characteristics of this type of waste, we began to redesign the coffee packaging, by proposing an alternative that focuses mainly on sustainability and circular economy. “La Peruana coffee”, indeed, originates benefits in the entire value chain of coffee: an added value concerns the use of its own by-products for the distribution of processed coffee to the final consumers in the city of Lima. The main benefit consists in reducing the environmental contamination caused by cumulated and badly processed agricultural waste, as well as preserving the environment by composting and recycling it. On the social side, we aim to reduce the excess work of farmers in burning and processing this waste matter, thus decreasing the atmospheric emissions they generate. In obtaining the raw material, therefore, we coordinate and help farmers in the processing before transporting it to the city of Lima where the packaging is developed. Additional benefits are produced throughout the products lifecycle by avoiding the manufacture and waste of single-use packaging such as plastic, and by promoting the use of ecological materials in Lima. Currently our packaging is sold in organic and ecological wineries that encourage the sustainable consumption of coffee, valuing the social responsibility of the product.

CONCLUSIONS

It is concluded that in Peru there is a large amount of agricultural residues that derive from the country's food production system. These agricultural and agro-industrial residues, which in total amount to 16 million tons per year in the country, have high potential of use for the development of new products based on organic fibres. Rice and coffee waste are poorly managed in the production areas, and thus it is essential to generate new alternatives of use, being coffee and rice products of international (and growing) demand.

Currently it can be observed a positive trend in using sustainable packaging, as consumers have started to value more social and environmental responsibility, according to the international consulting firms already mentioned in the development of the project. Therefore, we consider that our initiative can awake a great interest in continuing developing new basic products of organic and agricultural matter in the country.

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