

*Full Length Research Paper*

# **Substitution of non-biodegradable plastic food packagings by ecological food packagings at Abomey-Calavi University (Benin): State of place and microbiological quality of packagings**

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**Challenging with environmental problems and health due to non-biodegradable plastic wastes, Abomey-Calavi university heads have banned the use of any Non-biodegradable Plastic Food Packagings (NPFP) on all campuses. This study aimed to verify the effective implementation of this decision and assess the microbiological quality of ecological primary food packagings used in Abomey-Calavi campus. To achieve the objectives, a survey based on a questionnaire was submitted to actors in this policy (students, teachers, administrative officers and vendors). Microbiological quality evaluation of primary food packagings used consisted of counting the total mesophilic flora, total and thermo-tolerant coliforms, yeasts and molds through the basic laboratory methods. The results showed that 94,4% of Abomey-Calavi campus peoples are aware of the memo banning NPFP use within the university. They recognize that enormous risks of public health and ecosystem degradation are associated with the use of NPFP. Unfortunately, these pachagings continue to be used even though the trend is downward. The communication on ecological packagings benefits by university authorities remains insufficient. Also, some primary food packagings heavily used in this campus contains pathogenic microorganisms (thermotolerant coliforms and mycotoxinogenic molds) that can cause gastroenteritis and other food poisonings. People frequenting Abomey-Calavi campus remain permanently exposed to the risks associated with NPFP use. These packagings, especially that from food use constitutes potential and permanent sources of insalubrity, food poisoning, foodborne infection and intoxication.**

**Key words:** Plastic, packaging, microbiological quality, environmental pollution, health risk, food poisoning, foodborne infection.

## **INTRODUCTION**

Since prehistoric periods, packagings were used to contain a product and to preserve it from different

contaminations. They also allow and make easy items transportation, distribution, storage, display, use and

marketing. Packagings are mainly made with cardboard and paper, steel and metallic materials, glass, wood and plastics (Gontard, 2015).

Today, packagings are used in almost all areas of life, including the food industry. In fact, the population growing urbanization and the development of agrifood chains in the world have increased the demand of food packagings (Contreras, 2019). This is particularly observed in developing countries like Benin Republic. It is remarked a proliferation of plastic packagings, mainly in the agri-food industries which absorb around 65% of packagings produced in the world (Benslimane, 2014). The plastic food packagings are very practical, little cumbersome, aesthetic and particularly suited to the purchasing power of low-income populations. These people live really on the income from plastic packaging activities.

Unfortunately, plastic food packagings have tremendous effects. Most of them are non-biodegradable. They become very cumbersome and create serious environmental pollution problems. Then, when used, they are obviously difficult to manage by our development countries with limited resources (Onzo et al., 2016). The management system of plastic waste is a real challenge. The West African Economic and Monetary Union reported that, the rubbish dump in Benin republic would receive more than 12,000 tonnes of plastic waste per year, more than half of which is from the packaging bags thrown into the street after use (Quenum, 2019). Better still, package hot foods ready-to-eat in plastic packagings is a daily practice embedded in african populations' habits. This african common practice creates the chemical contamination risks with sanitary harmful effects in the short or long term. Indeed, several food additives and plastic residual monomers having a negative impact on consumers' health and product quality can migrate to packaged foods, especially liquid and fatty products (Guillard and Gontard, 2017). These plastic food packagings can therefore cause chemical, physical and microbiological contaminations of foodstuffs.

Faced with this situation, the head of Abomey-Calavi University issued a memo in 2013 banning the use of any non-biodegradable plastic food packagings on all university campuses. Recently, in 2017, Beninese National Assembly examined and unanimously passed the bill n° 2017-39, prohibiting the production, importation, marketing, possession and use of non-biodegradable plastic bags in the whole country. It is in this context that this study is carried out to (i) verify the effective implementation of the university staff memo banning non-biodegradable plastic food packagings use in the Campus of Abomey-Calavi University; (ii) assess the

university community knowledge level on the risks associated with the use of non-biodegradable plastic food packagings and (iii) assess the microbiological quality of ecological primary food packagings currently in use on this institution.

## MATERIALS AND METHODS

### Evaluation of the usage and risks knowledge associated with non-biodegradable food plastic packagings of university community members

The effective substitution of non-biodegradable food plastic packagings by ecological food packagings and knowledge level of university community members on the risks associated with them were evaluated through direct observations and a pre-established questionnaire. This questionnaire was filled out by students (212), teachers (26), administrative officers (22) and vendors (60). A total of 320 respondents were randomly selected at Abomey-Calavi campus in the district of Abomey-Calavi located at altitude of 12°, longitude 2° 21'20 East and latitude 6° 26'54 North in Benin Republic. It is the largest campus of Abomey-Calavi university. This list of question was relative to the sex, education level and profession of respondents; the knowledge of the ban on non-biodegradable plastic packagings use and their disadvantages, and current level use of non-biodegradable plastic packagings; the usual use of non-biodegradable plastic packagings and knowledge level of risks associated with use of non-biodegradable plastic food packagings; etc.

### Evaluation of microbiological quality of primary food packagings

Following the identification of different food packagings currently used at Abomey-Calavi campus, only main primary food packaging has been subjected to microbiological investigations.

#### Packagings sampling

Sixty food packagings were randomly sampled in restoration centers of Abomey-Calavi campus. Fifteen samples were collected per each type of packagings (A4 print paper, newsprint, single-use plate and multiple-use plate). Each packaging was placed in sterile sample bag and labeled. Thus, these collected samples were transported into an icebox at about 4°C to Laboratory of Microbiology and Food Technology (Abomey-Calavi university) for microbiological analysis.

#### Packagings microbiological analysis

The microbiological analysis consisted of stock solutions preparation and the various decimal dilutions which were subsequently inoculated on different culture media according to the microorganisms sought. Indeed, the stock solutions were prepared from the swab method. An area of 254 cm<sup>2</sup> has been delimited on

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each packaging. This area was swabbed. Then, the swab was introduced into buffered peptone water (10 ml) and homogenized to constitute the stock solution. Decimal dilutions were prepared according to the Speck (1976) method. The mesophilic aerobic flora were grown on Plate Count Agar according to the ISO 4833:2003 standard after incubation at 30°C for 72 h. Total and fecal coliforms were isolated on Crystal Violet and Neutral Red Bile and Lactose Agar after incubation respectively at 30°C (ISO 4832: 2006 standard) and 44°C (French standard 08-060: 2009) for 24 h. Finally, the yeasts and molds were grown on Sabouraud Agar enriched with Chloramphenicol after incubation at 25°C for 3 to 5 days according to French standard NF V08-059.

### Data processing and analysis

After manual tabulation of survey sheets, the data were encoded using Excel 2013 spreadsheet. This allowed the realization of descriptive statistics (mean, standard deviation and proportion) and various associated graphs. The data of each evaluated parameter were subjected to Analysis Of Variance (ANOVA) at probability level of 0.05 followed by the t-test "Least Significant Difference LSD" using Statistical Analysis System (SAS) version 8.1 software. Treatments were considered as a fixed factor while the repetitions were considered as a random factor (Dagnelie, 1998). Photoshop CS6 software was used to edit the different photos.

## RESULTS AND DISCUSSION

### Socio-demographic characteristics of respondents

Table 1 presents some socio-demographic characteristics of respondents involved in this study. Three hundred and twenty people including students (212), teachers (26), administrative officers (22) and vendors (60) were interviewed. This predominantly male group includes 122 women, that is, 38.13% of respondents. This gender trend is not very far from that of the university community, which between 2015 and 2016 recorded 27.8% of women (students, teachers and administrative officers) (Kpenavoun, 2017). However, this women proportion at Abomey-Calavi university (27.8%) is much lower than the national women proportion (51.2%) (INSAE, 2018). This gender difference at Abomey-Calavi university is due among other things to the low rate of girls schooling, to forced marriage, etc. The majority of respondents are literate (86.2%) and have received a university education (81.2%). This is quite normal since students constitute the majority of respondents (66.2%) and this study took place in high education institution.

### Effective substitution of non-biodegradable plastic packagings by ecological packagings

Table 2 provides information on effective substitution of non-biodegradable plastic packagings by ecological packagings at Abomey-Calavi university. About 95% of university community peoples is aware of the existence of

the rector's memo banning non-biodegradable plastic packagings use within the University. Those respondents unaware of this ban mainly include newly registered high school graduates, some distance learning students and those who hardly come to classes.

This study revealed the weakness of communication on the drawbacks of the use non-biodegradable plastic packagings (NPFP) by the University authorities. In fact, 76.9% of investigated people admitted that they had hardly been posted on the dangers due to these types of packagings. But more specifically, most of vendors (66.7%) and administrative officers (90.9%) were made aware of this situation. Indeed, several awareness sessions were organized by the rectoral authorities (Hygiene and Cleaning up Service) for vendors before the ban on NPFP use. Note also that 93.4% of the surveyed students did not receive any awareness session from the rectoral authorities before the implementation of the memo banning NPFP use. A priori, one would think that students might not be associated to that the communication on the dangers of NPFP use in the campus. This is not correct. Indeed, the rectoral authorities have signed a contract concerning the drawbacks of the NPFP use with the various student union organizations. Furthermore, students were educated and well informed through several methods including general meetings, information sessions in lecture rooms and posters. Unfortunately, these student unions did not honor their commitment and the contract was broken. The university authorities should check again and find another strong alternative solution.

The study also showed that the use of non-biodegradable plastic packagings particularly for foodpurpose has decreased significantly. Most of respondents (61.2%) greatly believe that plastic packagings are less-used on the Abomey Calavi campus. These results indicate that the substitution of non-biodegradable plastic packagings by ecological packagings is not yet quite effective. According to Agossadou (2016) in the early hours of the ban of these packagings use, the whole university community was voluntarily respecting or forced to respect this interdiction because the Hygiene and Cleaning up Service of university checks were carried out every fortnight. Several vendor's kiosks were closed during this period for not complying with this decision. Unfortunately, the control inspections were stopped. Thus, the use of non-biodegradable plastic packagings has gradually resumed on Abomey Calavi campus, especially in catering.

### Knowledge level of university community on risks associated with use of non-biodegradable plastic food packagings

The knowledge level of the respondents on the risks

**Table 1.** Socio-demographic profile of respondents

Characteristics	Staff	Percentage
<b>Sex</b>		
Male	198	61.9
Female	122	38.1
<b>Education level</b>		
Not literate	44	13.7
Elementary	16	05
Secondary	00	00
University	260	81.3
<b>Profession</b>		
Student	212	66.3
Administrative officer	22	06.9
Teacher	26	08.1
Vendors	60	18.7
<b>Alphabetisation</b>		
Yes	276	86.3
No	44	13.7

**Table 2.** Effective substitution of non-biodegradable plastic packagings at UAC

Characteristics	Students (n=212)(%)	Administrative officers (n=22) (%)	Teachers (n=26) (%)	Vendors (n=60) (%)	Total (n=320) (%)
<b>Knowledge of the ban on non-biodegradable plastic packagings use</b>					
Yes	91.5	100	100	100	94.4
No	08.5	00	00	00	05.6
<b>Sufficient awareness of the disadvantages of non-biodegradable plastic packagings use by the university authorities</b>					
Yes	06.6	90.9	00	66.7	23.1
No	93.4	09.1	100	33.3	76.9
<b>Sufficient awareness of the advantages of non-biodegradable plastic packagings use by the university authorities</b>					
Yes	05.7	00	15.4	20	08.7
No	94.3	100	84.6%	80%	91.3
<b>Current level use of non-biodegradable plastic packagings</b>					
Not used	04.7	00	00	10	05
Lightly used	64.2	72.7	69.2	43.3	61.3
Moderately used	18.9	09.1	15.4	46.7	23.1
Very used	11.3	18.2	15.4	00	10
Heavily used	0.9	00	00	00	0.6

associated with the use of non-biodegradable plastic packagings is summarized in Table 3. Firstly, we note that non-biodegradable plastic packagings is widely used

as primary, secondary and tertiary packagings. Primary food packaging is a packaging directly in contact with the food (water bottle, can drink, etc.) while a secondary food

**Table 3.** Respondents knowledge on risks associated with use of non-biodegradable plastic food packagings.

Characteristics		Students (n=106) (%)	Administrative officers (n=11) (%)	Teachers (n=13) (%)	Vendors (n=30) (%)
<b>Usual use of non-biodegradable plastic packagings</b>					
Primary packaging	Food use	66.0	100	69.2	80
	Non-food use	38.7	81.8	53.8	00
Secondaire packaging	Food use	77.3	72.7	69.2	16.7
	Non-food use	48.1	63.6	53.8	00
Tertiary packaging	Food use	38.6	18.2	53.8	00
	Non-food use	37.7	18.2	53.8	00
<b>Knowledge level of risks associated with use of non-biodegradable plastic food packagings</b>					
Risks recognition	Yes	98.1	100	100	93.3
	No	01.9	00	00	06.7
Environmental risks		63.2	90.9	69.2	66.7
Public health risks		79.2	72.7	76.9	80
<b>Sources of informations associated with use of non-biodegradable plastic packagings</b>					
Media		50	45.4	38.4	00
Academic education		33.9	27.2	15.4	00
Family education		06.6	00	00	00
Chat with friends		06.6	18.2	00	00
Environmental groups/structures		05.7	18.2	00	00

packaging (overwrap) brings together several consumption items in a single sale unit (packs) or highlights the primary packaging (mineral water pallets). Tertiary food packaging (logistics packaging) allows several products to be transported at the same time and groups them together for transport or palletization (Nkamba, 2011).

The respondents also use these non-biodegradable plastic packagings for non-food uses. However, almost all of the interviewees recognized that there enormous public health risks are associated with use of such packagings (Table 3). It should be noted that wrapping hot ready-to-eat foods in plastic packagings is a daily practice of african populations, particularly in Benin (Figure 1C, F and G). This common practice generates risks of food chemical contamination. The effects of this contamination can be harmful in the short or long term. Indeed, several food additives and residual plastic monomers wich having a negative impact on consumer health can migrate from packaging to packaged foods, particularly for liquid and fatty products (Gontard et al., 2017).

Indeed, the bisphenol A (a major component of conventional plastic packaging) is at the center of all scientific discussions for its toxicity. Also, some new cancers would be caused or aggravated by certain particles resulting from the degradation of plastic packagings. This is the reason why it is not recommended

to reuse plastic bottles (Figure 1 H). In addition, non-biodegradable plastic packagings poses environmental pollution including unhealthy cities, clogging of gutters (Onzo et al., 2013).

It is important to note that the media (radio, television, internet, etc.) and formal education constitute the main sources of information on the risks associated with the use of non- biodegradable plastic packagings in the surveyed community (Table 3). Discussions between classmates and within family units hardly address the problems related to use and management of non-biodegradable plastic packagings. In addition, the action of non-gouvernemental organizations and national institutions working in public health and environment protection is still not very perceptible even though the financial resources form national and international organizations increase every year. It is important and so urgent that african countries (particulary Benin Republic) improve their policies of food and non-food packagings management and focus communication efforts on grassroots communities, mainly in family units. Indeed, these families continue to burn non-biodegradable plastic bags for cooking fire. But how do you understand that people know and understand the risks associated with non-biodegradable plastic packagings and continue to use them?

Conventional or vegetable plastic is an exceptional



**Figure 1.** Main types of primary food packagings used on the Abomey-Calavi campus. [A, B, C]: Non-biodegradable plastic packagings; [D, M]: Non-biodegradable reusable composite packagings; [E]: Non-biodegradable and single-use polystyrene packagings; [F, G, H]: Reusable non-biodegradable plastic packagings; [I]: Reusable glass packaging; [J, K, L]: Biodegradable paper packagings; [N, O, P]: Some methods of packages conditioning; [Q]: Wash water of reusable packagings; [R]: Rinse water of reusable packagings.

material because of its lightness, malleability, impermeability, aesthetics, resistance, rigidity, flammability and above all its excellent quality/cost ratio (Madam, 2003). These properties are transferable to plastic food packagings. In Benin Republic, the population continues to use non-biodegradable plastic packagings because of (i) their low cost (from 0.009 \$), (ii) their accessibility (available everywhere, market, kiosk, shop, etc.) (Figure 1A, B), and above all, their very low availability of biodegradable plastic food packagings or any other types of ecological food packaging.

However, these available biodegradable plastic food

packagings cannot be used to package all types of food product. Indeed, the biodegradable food packaging available in Benin Republic is essentially based on paper and vegetable leaves (Figure 1J, K and L). These material cannot be used to efficiently package the large beniness food diversity. The available biodegradable plastic food packagings also tend to be more expensive than conventional plastic packaging.

In view of health and environmental damage due to the use of non-biodegradable plastic packagings and the progressive decrease in petroleum stocks, the plastics industry essentially dependent on fossil resources will

have to quickly find an alternative to the conventional raw materials it uses. One of the best alternatives is biopolymers use. Indeed, by their abundance and diversity, biopolymers offer a new source of renewable raw materials in the plastics industry. Gontard et al. (2017) reported that the main classes of vegetable biopolymers are (i) polysaccharides (starch, cellulose, agar, alginate, pectin, gums, xanthan, dextran, gellan, etc.), (ii) proteins (zein, gluten, polyamino acids, etc.), (iii) polyphenols (lignins, tannins, humic acids, etc.) and (iv) polyesters (polymers of lactic acids, polyhydroxyalkanoates, etc.). The biodegradability properties of these polymers constitute a solution to the environmental damages caused by the large tonnages of conventional plastic waste (Rabetafi ka, 2006).

### Microbiological quality of primary food packagings used on Abomey-Calavi campus

Among the primary food packagings identified on Abomey-Calavi campus, four widely used have been subjected to microbiological analyzes. These are Pack 1, a biodegradable A4 paper packaging obtained mainly by recycling of old university thesis (PhD, Master or Bachelor) and rejects from printing works (Figure 1J); Pack 2, biodegradable newsprint packaging obtained by recycling old newspapers, unsold newspapers and rejects from printers (Figure 1 K); Pack 3, non-biodegradable single-use polystyrene packaging obtained from trade (Figure 1E) and Pack 4, non-biodegradable multi-use composite packaging obtained from commerce (Figure 1D). Since the official ban of the university authorities, Pack 1 and 2 are in heavy use. These are very accessible to vendors, almost free or at negligible costs.

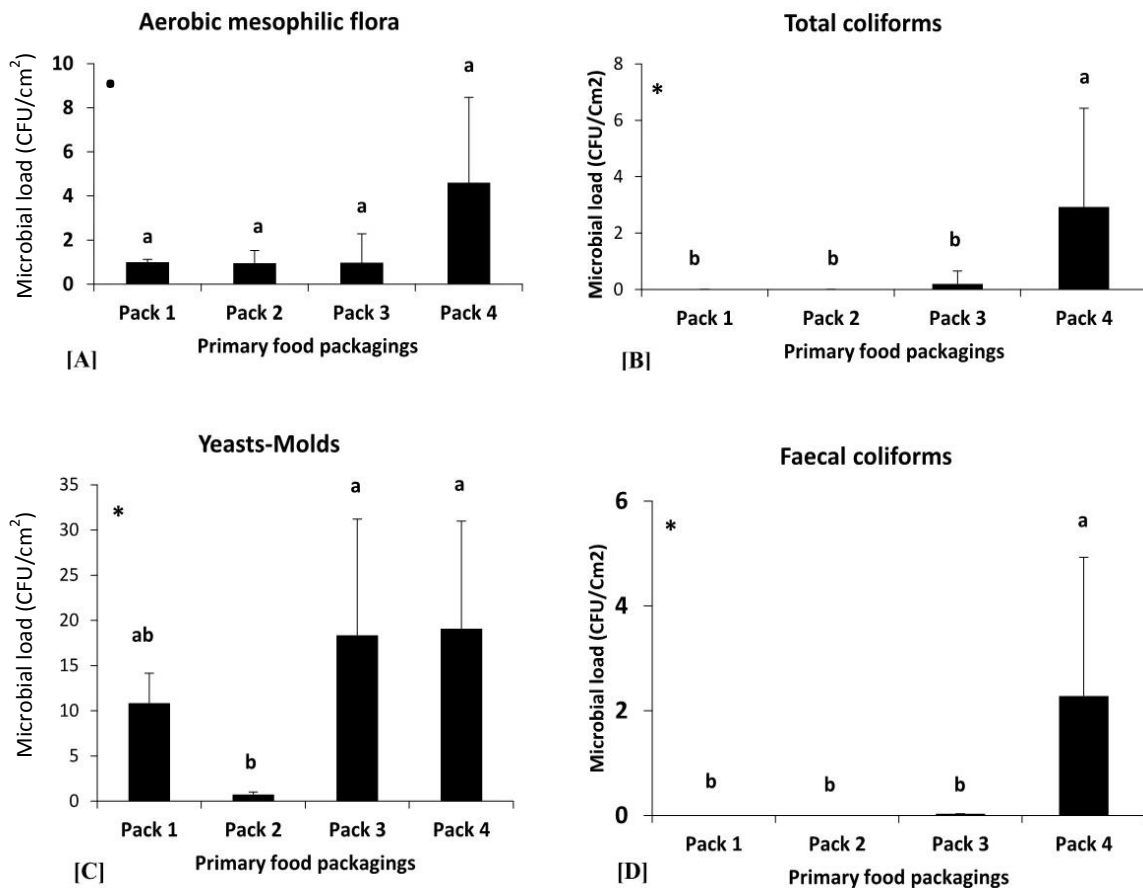
The microbiological quality evaluation consisted in the enumeration of Total Mesophilic Flora (TMF), Total Coliforms (TC), Fecal Coliforms (FC) and Yeasts-Molds (YM). Analysis of variance of microbial load revealed a significant difference ( $p < 0.05$ ) between different packagings for the parameters TC, FC and YM (Figure 2B, C and D). On the other hand, the microbial load difference of mesophilic flora is not statistically different ( $p > 0.05$ ) (Figure 2A). There is a strong variation in the microbial load both from one type of packaging to another and within samples of the same type of packaging. The large size of standard deviations show this precedent result. This microbial load variation may be related to the application degree of good hygiene practices which varies clearly from one vendors to another.

The paper packagings (Pack 1 and 2) did not contain coliforms (total and fecal) contrary to the packagings 3 and 4. The single-use polystyrene packaging (Pack 3) was however slightly contaminated by coliforms (Figure 1O, P). On the contrary, the coliform load was ten times

more abundant in non-biodegradable multi-use packaging (Pack 4) than single-use packaging (Pack 3). This result is not surprising, because the Pack 3 was single-use and better conditioned by the vendors (Figure 1O, P) when the Pack 4 are multi-use and the dishwashing stations do not respect any catering hygienic standards. Indeed, the dishwater used by the vendors is of insufficient quality (Figure 1Q, R). Better still, it is common to see the babies or childrens of the vendors defecating or taking their baths at the sale points. These practices contribute to the dissemination of pathogenic microorganisms from faecal origin. According to Ohin et al. (2018), the street food contamination by fecal coliforms could be linked to the use of untreated or poorly treated water, previously contaminated by animals and/or their excrement or by food handlers. Among the pathogenic germs from fecal origin, *Escherichia coli* represents 80 to 90% of fecal coliforms (thermotolerants). *E. coli* belong to natural microflora of the digestive tract of humans and warm-blooded animals (Moussé et al., 2015). But some strains are highly pathogenic. Indeed, the pathogenic microorganisms most involved in food poisoning are *Staphylococcus aureus*, *Salmonella* sp., *Clostridium perfringens* and *E. coli* (Moussé et al., 2015). *E. coli* is responsible for several diseases including the gastroenteritis. Although, it is often mild, it can sometimes have serious health consequences. Those most likely to be affected are children under the age of five, the elderly and people with weakened immune systems or with chronic diseases.

The results of this study also revealed packagings contamination by yeasts and molds (Figure 2C). The fungal load was significantly more abundant in the Packs 3 and 4 than that in the Packs 1 and 2. The most molds isolated belong to *Aspergillus* sp., *Fusarium* sp., and *Penicillium* sp. groups. The presence of these molds in primary food packagings is very worrying because they have a great toxic potential. Indeed, these molds produce several toxins named mycotoxins. Mycotoxins are among the most mutagens and carcinogens substances known. The prolonged exposure through food consumption has been linked to cancers and several diseases of the kidneys, liver and immune system (Tovide et al., 2017). It should also be noted the absence of aerobic sulfite-reducing bacteria in all investigated packagings.

The results of this study fill the informations gap on microbiological quality of food packagings both regionally and internationally area. Indeed, most of the studies carried out on microbiological quality of streed foods, both in Benin (Moussé et al., 2016; Sina et al., 2011), in Africa (Akusu et al., 2016; Bennani et al., 2016; Tchamba et al., 2015; Olorunjuwon et al., 2014; Koffi-Nevry et al., 2012; Barro et al., 2006, 2003) and worldwide (Dabboussi et al., 2013; Horton et al., 2011) focus mainly on the foodstuffs themselves and not on their packaging which is a potential and permanent source of



**Figure 2.** Microbiological diversity of primary food packagings used within Abomey-Calavi campus. **Pack 1** : Biodegradable A4 paper packagings ; **Pack 2** : Biodegradable newsprint packagings ; **Pack 3** : Non-biodegradable single-use polystyrene packagings; **Pack 4** : Non-biodegradable multi-use packagings. **[A]** : Distribution of aerobic mesophilic flora ; **[B]** : Distribution of total coliforms ; **[C]** : Distribution of yeasts-molds ; **[D]** : Distribution of faecal coliforms . : =  $p > 0.05$  (non significant) ; \* =  $p < 0.05$  (significant) ; \*\* =  $p < 0.01$  (very significant) ; \*\*\* =  $p < 0.001$  (very highly significant). On the same graph, the means with different letters are significantly different with probability level of 5 % according to LSD (Least Significant Difference).

microbiological contamination.

## Conclusion

Almost all of the Abomey-Calavi campus people are aware of the memo banning non-biodegradable plastic packagings use within the University. They also recognize that there are more risks to public health and ecosystem degradation associated with the use of these packagings. However, these non-biodegradable plastic packagings continue to be happily used even if the trend is downward. The communication on their disadvantages and the benefits of ecological packagings by university authorities remains insufficient. This observation might be extended at the national and regional levels. Therefore, West african countries should urgently improve their

policies for the management of both food and non-food packaging and concentrate communication efforts on grassroots communities, mainly family units. The adoption of ecological packagings is now a national, regional and global challenge. It should also be noticed that some primary food packagings heavily used on the Abomey-Calavi campus contains pathogenic microorganisms that can cause gastroenteritis and microbial infections of varying danger degrees. These packagings constitute potential and permanent sources of food poisoning. A public health problem therefore arises and requires the support of both ministries of Health and Environment Protection.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.



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