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Preface

We would like to present, with great pleasure, the inaugural volume-6, Issue-6, June 2020, of a scholarly journal, *International Journal of Engineering Research & Science*. This journal is part of the AD Publications series *in the field of Engineering, Mathematics, Physics, Chemistry and science Research Development*, and is devoted to the gamut of Engineering and Science issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

This journal was envisioned and founded to represent the growing needs of Engineering and Science as an emerging and increasingly vital field, now widely recognized as an integral part of scientific and technical investigations. Its mission is to become a voice of the Engineering and Science community, addressing researchers and practitioners in below areas

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Neural Networks	Plastic Engineering

Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with IJOER. We are certain that this issue will be followed by many others, reporting new developments in the Engineering and Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOER* readers and will stimulate further research into the vibrant area of Engineering and Science Research.

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Use of Triple Bagging System and Biopesticides for the Optimization of Storage Methods of Corn Grains for an Application in Oil Industry

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Abstract— *Corn is the second most cultivated cereal in Ivory Coast after rice. The grain germ represents an important source of quality fat, which could fill the deficit in fat both in populations and in industries. Unfortunately, grain production and the quality of fat are affected by storage methods that are often harmful to health. It is in this context that in the present study carried out in Ivory Coast. Surface response methodology (3-factor Central Composite Design) was conducted to monitor the effectiveness of triple bagging system and biopesticide (leaves of Lippia multiflora and Hyptis suaveolens) on the stability of some alteration parameters of the grains intended for use in oil mills. Thus, humidity, peroxide index and acidity were assessed during storage. The independent variables considered were the storage duration (1 to 18 months), the biopesticide / corn ratio (0 to 5%) and the combination of biopesticides (0 to 100% Lippia). Predictive regression equations were constructed for the estimation of each parameter studied (R^2 > 0.70). An increase in grain moisture, peroxide index and acidity (P <0.01) was observed with the storage time. However, a threshold concentration of biopesticides has been shown to be effective for the stability of spoilage parameters. The optimization of the results made it possible to determine the ideal conditions for the conservation of the corn kernels. Thus, the addition of 2.5% of biopesticides (20% of Lippia multiflora and 80% Hyptis suaveolens) in a triple bagging system is effective for the stability of the alteration parameters for 18 months. Under these ideal conditions, the experimental values are respectively of the order of 12.30 ± 0.17%; 3.96 ± 0.14 meq O_2 / kg and 3.18± 0.08% respectively for humidity, peroxide index and acidity. These values considered to guarantee quality stability are statistically (P> 0.05) equal to those predicted by the mathematical model.*

Keywords— **Corn storage, triple bagging, biopesticides, lipid quality, surface methodology responses.**

I. INTRODUCTION

In Ivory Coast, maize is the second most cultivated cereal after rice (Akanvou *et al.*, 2006). Currently, annual national production is around one million tonnes (FAO, 2017). Used in the preparation of several dishes (boiled, roasts, "tô" or even as a local beer "Tchapalo"), corn constitutes a staple food of a good part of the Ivorian populations in rural areas (Yao *et al.*, 2013).

Corn kernels are an important source of fat, the oil extracted from the seed germ is considered one of the best edible vegetable oils because of its richness in essential nutrients (unsaturated fatty acids, tocopherols and phytosterol) (Shende and Sidhu, 2014). Therefore, its consumption would represent an advantage for human health (Dubois *et al.*, 2007). In addition, the production of corn oil in quality and quantity could fill the shortage of fat that has existed for years in populations and industries. Thus, the mastery of good post-harvest practices and especially that of the conservation of corn kernels becomes very important insofar as the quality of the oil depends on the quality of grain storage.

Unfortunately, storage poses many problems for players in the corn sector, which record huge post-harvest losses throughout the year (Johnson *et al*., 2012). In order to store corn crops longer, producers use synthetic chemical pesticides to treat stocks. The abusive and non-regulatory use of these chemical inputs beyond their dangerousness on the environment, human and animal health is currently a major concern for oil manufacturers (Pagès *et al.*, 2010). In fact, the use of synthetic pesticides leads to the passage of residues from the surface of the grains to fat (Lacoste *et al*., 2005).Once extracted, the crude oil contains considerable quantities sometimes higher than the limits set by the European Union of organochlorine, organophosphorus pesticides and carbamates used in post-harvest by producers (Pagès *et al*., 2010). In addition, under uncontrolled storage conditions, hydrolysis and oxidation products are added to these residues (free fatty acids, partial glycerides, hydrocarbons, aldehydes and ketones) which affect the quality of the oil (Cmolik and Pokorny, 2000; Pages *et al.*, 2010). However, simple, effective, less expensive methods guaranteeing human health seem to exist in rural areas for the protection of stocks. Among these methods, the use of plant-based biopesticides (aromatic and derived plants) is a topical research subject in Côte d'Ivoire. Among these aromatic plants, *Lippia multiflora* and *Hyptis suaveolens* are well known to populations in Côte d'Ivoire in rural areas for various uses (Tia, 2012; Ekissi, 2014) and in particular in the field of cereal and legume conservation (Niamketchi, 2017; Ezoua, 2019)

In addition, triple bottom bags made of a double layer of independent polyethylene put inside a woven polypropylene bag have shown their effectiveness in extending the storage life of cowpea (Konan, 2017; Fofana, 2019).

Thus, the objective of this study is to assess the effectiveness of a triple bagging system and biopesticides on the quality of corn kernels intended for industrial use in oil mills. Corn kernel of conservation tests are based on the use of a central composite design. It is a surface response methodology allowing to optimize post-harvest storage by determining an ideal proportion and / or combination (minimal and effective) of leaves of *Lippia multiflora* and *Hyptis suaveolens* to stabilize in a lasting way the parameters of alteration of the lipid quality of the grain.

II. MATERIAL AND METHODS

2.1 Study site

The experimental tests were carried out in the conservation chamber of the Laboratory of Biochemistry and Food Sciences (LaBSA) at the Félix Houphouët-Boigny University. Within this enclosure, the average temperature and relative humidity were respectively around 27.27ºC ± 1.41 and 81.58 ± 3.02%. The storage bags were placed on wooden pallets as a support.

2.2 Biological material

2.2.1 Corn used in the study

The dry corn kernels used in this study were obtained from producers in the Hambol region in north-central Côte d'Ivoire in the department of Katiola, between 8 ° 10'North and 5 ° 40' West, just after harvest. It is an improved variety GMRP-18 of yellow morphotype and is characterized by a short production cycle of 90-95 days.

2.2.2 Selected plants

The leaves of *Lippia multiflora* and *Hyptis suaveolens*, were harvested in the region of Gbêkê (7°50'North and 5°18' West). They were dried out of the sun for a week and then chopped into fine particles before use.

2.2.3 Packaging equipment

Polypropylene and polyethylene bags with a capacity of 120 kg were obtained from suppliers in the Adjamé market (commune of Abidjan) for the storage of corn. The triple bagging system consisted of a combination of two internal polyethylene bags (high density with a thickness of 80 mm and not very breathable) and an external bag in synthetic fabric (polypropylene).

2.3 Methods

2.3.1 Maize grains storage methods

The experiment was carried out over a period of 18 months. It was implemented on the basis of an experimental design (central composite design) using the storage method by bagging corn kernels with or without the leaves of *Lippia multiflora* and / or *Hyptis suaveolens*. Nine experimental batches and one control batch were established as follows: **TSP :** control batch ; 50 kg maize kernels stored in a polypropylene bag**, MET 1:** 1st experimental sample ; 50 kg of maize kernels stored in a triple bagging system with 0 % of biopesticides, **MET 2 :** 5th experimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 1.01 % of biopesticides (0.10 kg of *L. multiflora* leaves and 0.40 kg of *H. suaveolens* leaves*)*, **MET 3 :** 6th experimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 1.01 % of biopesticides (0.40 kg of *L. multiflora* leaves and 0.10 kg of *H. suaveolens* leaves), **MET 4 :** 2nd experimental sample; 50 kg of maize kernels stored in a triple bagging system containing 2.5 % de biopesticides (0.625 kg of *L. multiflora* leaves and 0.625 kg of *H. suaveolens* leaves*)*, **MET 5 :** 8th experimental sample; 50 kg of maize kernels stored in a triple bagging system containing 2.5 % of biopesticides (1.25 kg of *L. multiflora* leaves*)* and **MET 6 :** 9th experimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 2.5 % of biopesticides (1.25 kg of *H. suaveolens* leaves) ; **MET 7:** 4thexperimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 3.99 % of biopesticides (1.60 kg of *L. multiflora* leaves and 0.40 kg of *H. suaveolens* leaves *)*,**MET 8 :** 3rd experimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 3.99 % of biopesticides (0.40 kg of *L. multiflora* leaves and 1.60 kg *H. suaveolens* leaves), **MET 9 :** 7th experimental sample ; 50 kg of maize kernels stored in a triple bagging system containing 5 % of biopesticides (1.25 kg of *L. multiflora* leaves and 1.25 kg of *H. suaveolens* leaves*)*.The bags were filled by alternating the corn kernels and the leaves of *Lippia multiflora* and / or *Hyptis suaveolens* in the form of strata.

2.3.2 Central composite design application

A central composite design with three variables was implemented in order to find the best proportion and / or combination of biopesticides to preserve the quality parameters of the corn kernels. The three factors or technological parameters taken into account in this study were: the storage period of the corn kernels (months), the biopesticides / Corn ratio (%) and the combination of biopesticides (*Lippia multiflora* and *Hyptis suaveolens*; with% of *Lippia multiflora* as reference) (Table 1). In this plan, each factor presented 5 levels (-1.682, -1, 0, +1 and +1.682). Thus, 20 tests comprising 8 factorial tests, 6 star tests and 6 tests at the center of the experimental field (Table 2) were carried out according to the principle of use described by Feinberg (1996). These, corresponding to the different samples taken, were carried out according to the experimental matrix. The coded values of the parameters were replaced by the real values of the factor levels, by randomization of the trials (Table II). For each test, according to the fixed values of the factors, the preservation methods were assessed in relation to the following answers: the moisture content of the grains (Y_1), the peroxide index (Y_2) and the acidity (Y_3).The results of each response obtained are linked to the 3 independent variables by a second-degree polynomial model of the following form as described by Tinsson (2010) and Koffi *et al*. (2015):

$$\mathbf{Yn} = b0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 + b_{11}X^2_1 + b_{22}X_2^2 + b_{33}X_3^2$$

Where **Yn** is the experimental response and $\mathbf{X_1}$**,** $\mathbf{X_2}$ and X_3correspond to the technological parameters namely the shelf life, the biopesticide / maize ration and the biopesticide combination respectively, $\mathbf{b_n}$the values of represent the corresponding regression coefficients.

TABLE 1
INDEPENDENT VARIABLES AND THEIR CODED AND ACTUAL VALUES USED

Independent variables	Coded levels				
	-1.682	**-1**	**0**	**1**	**1.682**
X_1 : Storage time (month)	1	4.45	9.5	14.5	18
X_2 : biopesticides/ maize ratio (%)	0	1.01	2.5	3.99	5
X_2 : Combination of biopesticides (% *Lippia*)	0	20.27	50	79.73	100

TABLE 2
ESTABLISHMENT OF EXPERIMENTAL TABLE TEST OF THE CENTRAL COMPOSITE DESIGN (CCD)

Run order	Coded values and real levels of parameters		
N°	X_1(month)	X_2 (%)	X_3(month)
1	-1 (4.5)	-1 (1.01)	-1 (20.27)
2	1 (14.5)	-1 (1.01)	-1 (20.27)
3	-1 (4.5)	1 (3.99)	-1 (20.27)
4	1 (14.5)	1 (3.99)	-1 (20.27)
5	-1 (4.5)	-1 (1.01)	1 (79.73)
6	1 (14.5)	-1 (1.01)	1 (3.99)
7	-1 (4.5)	1 (3.99)	1 (3.99)
8	1 (14.5)	1 (3.99)	1 (3.99)
9	-1.682 (1)	0 (2.5)	0 (2.5)
10	1.682 (18)	0 (2.5)	0 (2.5)
11	0 (9.5)	-1.682 (0)	0 (2.5)
12	0 (9.5)	1.682 (5)	0 (2.5)
13	0 (9.5)	0 (2.5)	-1.682 (0)
14	0 (9.5)	0 (2.5)	1.682 (5)
15	0 (9.5)	0 (2.5)	0 (50)
16	0 (9.5)	0 (2.5)	0 (50)
17	0 (9.5)	0 (2.5)	0 (50)
18	0 (9.5)	0 (2.5)	0 (50)
19	0 (9.5)	0 (2.5)	0 (50)
20	0 (9.5)	0 (2.5)	0 (50)

X1= Storage duration; X2= biopesicdes / maize ratio; X3 = Combination of biopesticides

During the experiment, on the dates provided (1, 4.5, 9.5, 14.5 and 18 months) by the CCD for the samples,5 kg of corn kernels with different strata inside the bags (above, center, bottom and lower sides) were sampled by random punctures from each batch indicated by the matrix of the experiments.

2.3.3 Determination of grain moisture content

The evolution of the moisture content of the corn kernels during storage was determined by parboiling according to the method of standard 952.08 (AOAC, 2000). It is based on dehydration by drying, in the samples oven, until a constant weight is obtained.

2.3.4 Determination of peroxide index

The determination of the peroxide index of the fat content of the corn samples was carried out by the method described by standard 965.33 (AOAC, 2000). This method consisted in treating a test sample of fat solubilized in a mixture of chloroform and acetic acid, with a saturated solution of potassium iodide, then in titrating the iodine liberated with a solution of sodium thiosulfate.

2.3.5 Determination of Free fatty acid pourcentage

The determination of the acidity of the fat in the corn samples was determined according to standard 940.28 of AOAC (2000). This method consisted in titrating with an alcoholic potassium hydroxide solution (0.5 N) in the presence of phenolphtalein, the acidity of a fat sample initially dissolved in a mixture of ethanol-diethyl ether solvents (1:1, v/v) until turning pink.

2.4 Statistical analysis

All tests were carried out in triplicate. Statistica version 7.1 software was used to process the data recorded in the tables and figures representing the mean values ± the standard experimental deviations. Thus a multiple linear regression analysis was performed. The experimental data were fitted according to the second order polynomial equation model and the regression coefficients were obtained. According to experimental data, the suitable model represented by the equation has been constructed and the statistical significance of the model limits has been examined by regression analysis and analysis of variance (ANOVA)

III. RESULTS

3.1 Results of central composite design

A central composite design was used to determine the best conditions for storing corn in triple bottom bags. This experimental design was developed as presented in Table 3. The latter also presents the experimental values obtained for the humidity, the peroxide index as well as the acidity.

TABLE 3
CENTRAL COMPOSITE DESIGN AND EXPERIMENTAL RESPONSES

Run	Real level values of paramters			Experimental responses		
	X_1 (month)	X_2 (%)	X_3 (%lippia)	Y_1 (%)	Y_2 (meq O2/kg)	Y_3 (%)
1	4.45	1.01	20.27	10.50±0.01	3.31±0.01	2.57±0.05
2	14.5	1.01	20.27	12.00±0.02	4.12±0.02	3.55±0.10
3	4.45	3.99	20.27	10.05±0.01	2.90±001	2.21±0.05
4	14.5	3.99	20.27	11.25±0.01	3.54±0.01	2.80±0.09
5	4.45	1.01	79.73	11.00±0.01	3.04±0.01	2.81±0.01
6	14.5	1.01	79.73	12.30±0.01	3.97±0.01	3.75±0.03
7	4.45	3.99	79.73	10.40±0.01	2.80±0.01	2.39±0.06
8	14.5	3.99	79.73	11.45±0.01	3.38±0.01	2.92±0.07
9	1	2.5	50	09.15±0.25	1.39±0.25	1.30±0.03
10	18	2.5	50	12.35±0.02	4.07±0.02	3.31±0.07
11	9.5	0	50	12.00±0.00	6.11±0.00	4.80±0.07
12	9.5	5	50	10.95±0.01	3.09±0.01	2.30±0.01
13	9.5	2.5	0	11.20±0.00	3.05±0.00	2.88±0.00
14	9.5	2.5	100	11.50±0.01	3.12±0.01	3.07±0.00
15	9.5	2.5	50	11.10±0.01	3.27±0.01	2.92±0.00
16	9.5	2.5	50	11.29±0.01	3.90±0.01	2.72±0.05
17	9.5	2.5	50	10.98±0.02	3.12±0.02	3.00±0.17
18	9.5	2.5	50	11.08±0.07	3.31±0.07	2.35±0.12
19	9.5	2.5	50	10.84±0.10	3.29±0.03	3.40±0.09
20	9.5	2.5	50	11.12±0.09	3.00±0.09	2.93±0.09

The determination of experimental responses were performed in triplicate X1= storage time; X2= biopesticides /maize ratio; X3 = Combination of biopesticides; **Y1 = Moisture; Y2 = peroxide index; Y3 = Acidity.**

3.1.1 Fitting of the model

The different values of the coefficients of determination R^2 and R^2 adjusted for the regression model of humidity, peroxide index and acidity are indicated in Table IV. These values being greater than 0.70 for R^2 (respectively 0.95; 0.81 and 0.85) with respective adjusted R^2 of 0.91; 0.65; 0.71 allows us to say that the models of the predicted second degree polynomial have clearly defined the real behavior of the equation system. In fact, ANOVA has shown that the variabilities observed were due to the different models. Their non-significant adjustment faults also showed that these models are well adjusted, thus justifying the adequacy of the model to predict exactly the variations.

TABLE 4
REGRESSION COEFFICIENTS OF PREDICTED QUADRATIC POLYNOMIAL MODELS FOR MOISTURE, PEROXIDE INDEX AND ACIDITY

Coefficients		Coefficients estimated		
		Humidity (Y1)	Peroxide Index(Y2)	Acidity (Y3)
	b_0	11.07^{***}	3.32^{***}	2.89^{***}
Linear				
	b_1	0.76^{***}	0.54^{**}	0.47^{***}
	b_2	-0.32^{***}	-0.50^{***}	-0.48^{***}
	b_3	0.14^{*}	-0.04^{ns}	0.08^{ns}
Quadratics				
	b_{11}	-0.13^{ns}	-0.23^{ns}	-0.22^{ns}
	b_{22}	0.12^{ns}	0.43^{**}	0.22^{ns}
	b_{33}	0.08^{ns}	-0.10^{ns}	0.02^{ns}
Interaction				
	b_{12}	-0.07^{ns}	0.06^{ns}	-0.10^{ns}
	b_{13}	-0.04^{ns}	0.01^{ns}	-0.01^{ns}
	b_{23}	-0.03^{ns}	0.03^{ns}	-0.17^{ns}
R^2		0,95	0,81	0,85
R^2 ajusted		0,91	0,65	0,71
***p*-lack of fit**		0.10^{ns}	0.06^{ns}	0.36^{ns}

***Significant at P= 0.05 ;** Significant at P = 0.01 ; *** Significant at P = 0.001 ; ns : no significant ; R² : Regression coefficient; p-lack of fit : Probabilité du défaut d'ajustement ; b1, b2 and b3 = linear regression coefficients respectively of X1, X2 and X3 ; b12 = regression coefficients of interaction between X1 and X2 ;b13= regression coefficients interaction between X1 and X2 ; b23= regression coefficients of interaction between X2 and X3 ; b11= quadratic regression coefficient of X1 ; b22= quadratic regression coefficient of X2 ; b33= quadratic regression coefficient of X3**

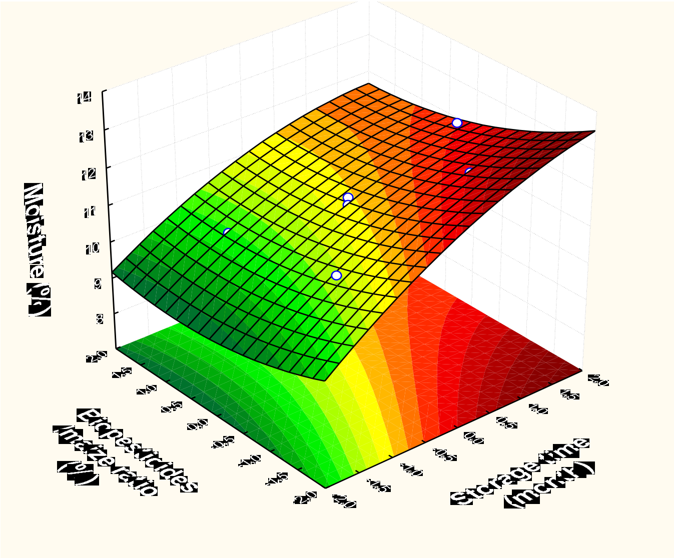
3.1.2 Effects of factors on grains moisture

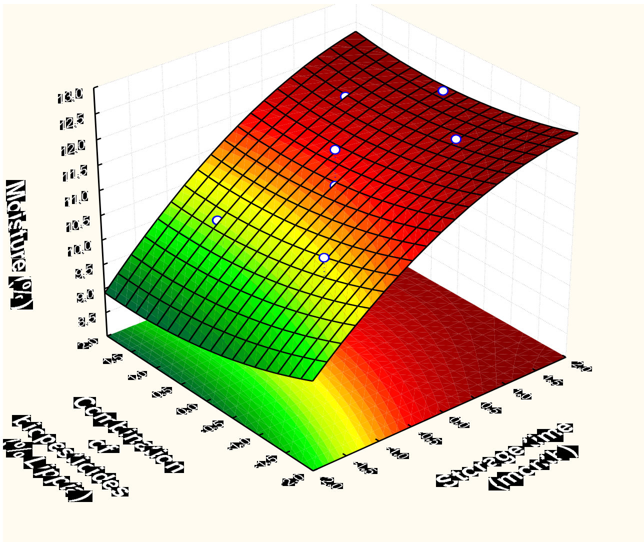
The results of the statistical analysis of the effects of the variables shelf life, biopesticide / maize ratio and combination of biopesticides on the moisture content obtained, based on the central composite design are shown in Table 4. Multiple regression analysis is performed on the experimental data and the model coefficients are evaluated for significance. Thus, the shelf life, the biopesticides / corn ratio and the combination of biopesticides have significant effects (P <0.001 and P <0.05). The following relation gave the final predictive equation for the humidity level (Y_1) neglecting non-significant factors:

$$Y_1 = 11.07 + 0.76X_1 - 0,32X_2 + 0,14X_3$$

All the linear coefficients of the variables (X_1, X_2 and X_3) are significant (P <0.05). Significant terms have a remarkable impact on the moisture content of grains while non-significant terms (all interactions as well as quadratic terms) have a negligible influence. In order to assess the effects of the three factors on the moisture content of corn kernels during storage, “Fig. 1” is constructed from the above equation. This figure shows the effects of duration (X_1), the proportion of biopesticides (X_2) and the combination of biopesticides (X_3) on the humidity level.

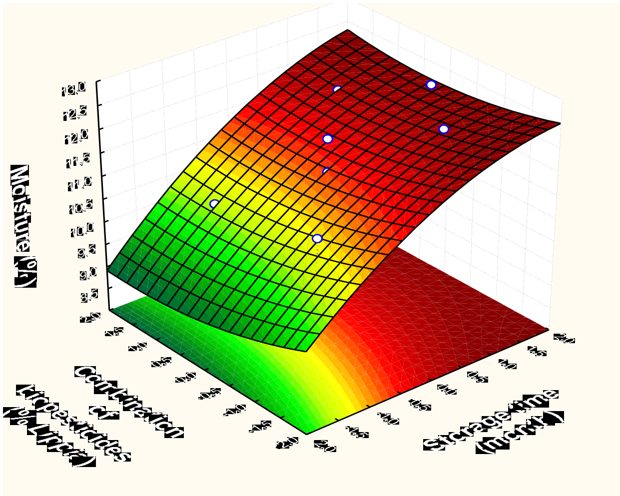
“Fig. 1A” shows the effect of the duration (X_1) and of the proportion of biopesticides (X_2) by keeping the combination of biopesticides constant at its zero level. The increase in storage time leads to an increase in the moisture content of the grains. On the other hand, an increase in the quantity of biopesticides has a negative effect on the increase in the humidity of the grains during storage. “Fig. 1B” shows the interaction between the duration (X_1) and the combination of biopesticides (X_3) by keeping the ratio of biopesticides constant at its average value (2.5%). The variation in the combination has a lesser negative effect on the increase in humidity. “Fig. 1C” indicates that by increasing the proportion of biopesticides and that of Hyptis in particular with the duration kept constant (9.5 months), the increase in the moisture content of the grains is strongly inhibited.





A) = Interaction between storage time (X1) and biopesticides ratio (X2) with X3 = 0

B) = Interaction between storage time (X1) and biopesticides combination (X3) with X2 = 0



C) = Interaction between biopesticides ratio (X2) and biopesticides combination (X3) with X1 = 0

FIGURE 1: Effects of different factors on grains moisture

3.1.3 Effects of factors on peroxide index

The results of the experimental design show that the values obtained for the peroxide index, from the different types of packaging after 9.5 months of storage, are 6.11 ± 0.00 meq O2 / kg for the batch in a triple bagging system without biopesticides and 3.09 ± 0.01 meq O2 / kg in the lot in triple bagging system with 5% biopesticides. Using a multiple regression analysis, the relationships examined between the independent variables (X_1, X_2 and X_3) and the peroxide index were expressed according to the equation below:

$$\mathbf{Y_2 = 3.32 + 0.54X_1 - 0{,}50X_2 + 0{,}43X_2^2}$$

The linear coefficients of the variables and and the quadratic term are significant (P <0.01). Thus, the effect of the storage time and the biopesticides / corn ratio have a remarkable impact on the peroxide index of the grain oil. On the other hand, the terms linear, quadratic and the interaction between the variables (X_1, X_2 and X_3) are not significant (p> 0.05) and have a negligible influence on the peroxide index. The effect of the factors on the peroxide index is illustrated in "Fig. 2." The external surface of this figure shows that the peroxide index increases with the storage time. However, an increase in the proportion of biopesticides inhibits the development of the peroxide index during the shelf life.

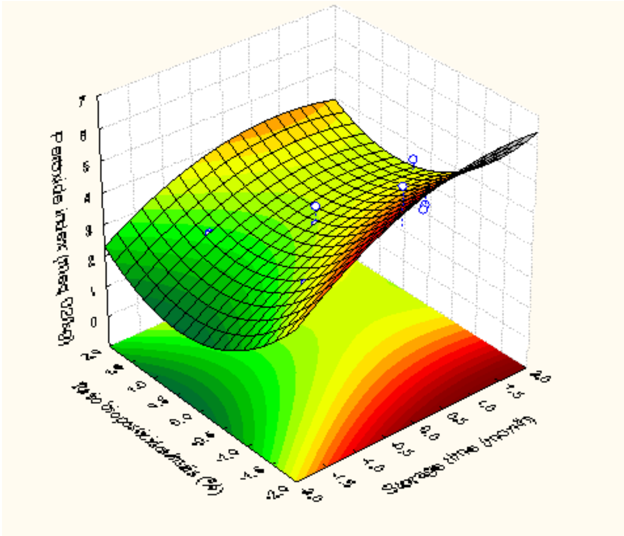


FIGURE 2: Effects of different factors on peroxide index

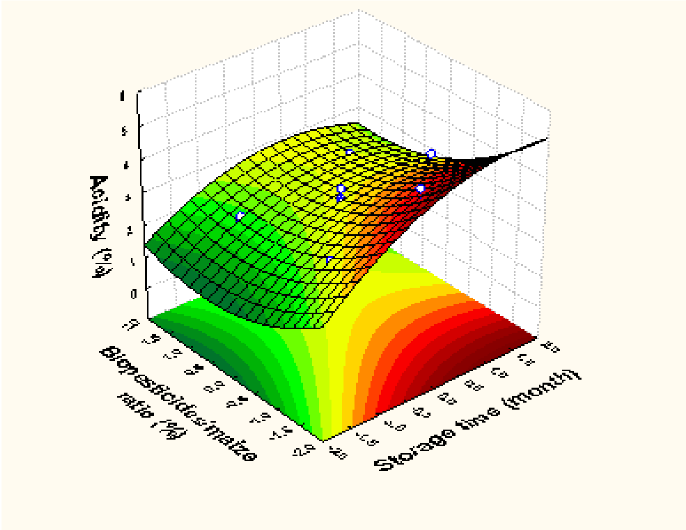


FIGURE 3:Effects of different factors on acidity

3.1.4 Effects of factors on acidity

The multiple linear regression analysis performed from the experimental data made it possible to evaluate the significant coefficients of the model. The values of the latter are given in Table 4. Thus, the final predictive equation of acidity (Y_3) shows that the storage duration and the ratio of biopesticides have significant effects. It looks like this:

$$Y_3 = 2.89 + 0.47X_1 - 0.48X_2$$

The variables and, having linear coefficients are very significant (P <0.01) and have a remarkable impact on acidity. Whereas, the non-significant terms (the term, all interactions as well as the quadratic terms) have a negligible influence. In order to assess the effects of the two factors on the values of the acidity of the oil in the corn kernels during storage, Figure 3 is constructed from the above equation. This figure shows the effects of duration (X_1) and the proportion of biopesticides (X_2) on acidity. In general, the acidity increases with the duration of storage, while an increase in the proportion of biopesticides has a negative effect on the development of acidity over time.

3.2 Validation and experimental verification of methods used

To determine the ideal storage conditions, the desirability function was used, thus the results of the experimental analysis through this function show that the storage of grains to maintain the alteration parameters is favored when the variable storage duration (X1) is at its highest level (+ 1.682), the variable biopesticides / corn ratio (X2) at level (0) and the coded value of the combination of biopesticides (X3) is (-1).Thus, the ideal process for preserving corn kernels is carried out under the following conditions:

- Storage duration : 18 Months
- Biopesticides / maize ratio : 2.5 %
- Combination of biopesticides : 20 % of *Lippia multiflora* and 80 % of *Hyptis suaveolens*

Using the desirability function of the surface response method of Statistica version 7.1 software, the ideal conditions for storing corn kernels were predicted with 2.5% biopesticides including 20% *Lippia multiflora* and 80% *Hyptis suaveolens* for 18 months in triple bottom bags, the largest possible values for the parameters for altering the quality of the fat content of the grains have been determined (Table 5). Under these conditions mentioned above, the experimental results are very close to those predicted (Table 5). For parameters, humidity, peroxide and acidity, the experimental values also obtained under these same conditions, always remain much lower as well as those obtained in the polypropylene control batch than with those obtained with the batch in triple bagging system without biopesticides (Tables 5 and 6). Moreover, for the two types of bag used without biopesticides polypropylene and triple bagging system) for a period of 9.5 months, the values obtained for the moisture, peroxide index and acidity in the batch with the triple bagging system (MET 1) remain much lower those of the control batch with polypropylene bag (TSP).

TABLE 5
EXPERIMENTAL VALUES UNDER IDEAL CONDITIONS AND CONTROL BAG (TO 9.5 MONTHS)

Responses	Ideal conditions (triple bagged with biopesticides)		Control bag
	Predicted values	Obtained values	TSP (9.5 months)
Moisture (%)	12.01^{b}	12.30±0.17^{b}	16.67±0.27^{a}
Peroxide index (meq O_2/kg)	3.52^{b}	3.96±0.14^{b}	10.48±0.21^{a}
Acidity (%)	3.01^{b}	3.18±0.08^{b}	9.16 ±0.05^{a}

The determinations of experimental responses were performed in triplicate. The values on the same line presenting the same signs are statistically in the same homogeneous group with P = 0.05

TABLE 6
EXPERIMENTAL VALUES UNDER IDEAL CONDITIONS AND TRIPLE BAGGED LOT WITHOUT BIOPESTICIDES AT 18 MONTHS

Responses	Ideal conditions (triple bagged with biopesticides)		triple bagging with biopesticides batch
	Predicted values	Obtained values	MET 1
Moisture (%)	12.01^{b}	12.30±0.17^{b}	13.01±0.10^{a}
Peroxide index (meq O_2/kg)	3.52^{b}	3.96±0.14^{b}	10.66±0.07^{a}
Acidity (%)	3.01^{b}	3.18±0.08^{b}	7.92±0.01^{a}

The determinations of experimental responses were performed in triplicate. The values on the same line presenting the same signs are statistically in the same homogeneous group with P = 0.05

TABLE 7
OBTAINED VALUES AFTER 9.5 MONTHS IN CONTROL BAG AND TRIPLE BAGGED LOT WITHOUT BIOPESTICIDES

Responses	Without biopesticides	
	Polypropylene bag	Triple bagging lot
Moisture (%)	16.67±0.20^{a}	12.00 ±0.04^{b}
Peroxide index (meq O_2/kg)	10.48±0.04^{a}	6.18±0.19^{b}
Acidity (%)	9.16±0.32^{a}	5.00±0.02^{b}

The determinations of experimental responses were performed in triplicate. The values on the same line presenting the same signs are statistically in the same homogeneous group with P = 0.05

IV. DISCUSSION

This study showed that the conservation of corn kernels in triple bottom bags in the presence of leaves of *Lippia multiflora* and *Hyptis suaveolens* makes it even more effective to maintain the parameters of alteration of the kernel fat content. Indeed, low moisture content of corn kernels has been observed in the presence of biopesticides during storage. Moreover, inhibition of the development of the peroxide index and of the acidity was observed from a threshold concentration of biopesticides which is 2.5% of leaves of *Lippia multiflora* and *Hyptis suaveolens*. This minimum proportion of biopeticides (2.5 with 20% of *Lippiamultiflora* leaves and 80% of *Hyptis suaveolens* leaves) has proved effective in preserving over a period of 18 months the parameters of alteration of corn kernels in order to use in oil industry.

After the first 9 and a half months of storage, the results obtained for the corn kernels in the triple bagging systems associated or not with the leaves of *Lippia multiflora* and / or *Hyptis suaveolens* indicate the stability of the alteration parameters. In these storage systems, the values measured for humidity, peroxide index and acidity change very little unlike the control batch made of polypropylene. Changes in the moisture content of corn kernels show that keeping this parameter at a suitable threshold (<13%) during storage is important to delay the first biochemical reactions (oxidative and hydrolytic rancidity) and proliferation weevils who would favorite the alteration of the lipid quality of the grains. However, after the first 10 months of storage, the experimental values obtained for the parameters (humidity, peroxide index and acidity) at the level of the grains stored in triple bagging systems without biopesticides, remain high compared to those of batches in triple bagging with biopesticides at the end of the experiment, these values reflect the effectiveness of the leaves of *Lippia multiflora* and / or *Hyptis suaveolens* as biopesticides in the storage of corn kernels intended for use in oil mills. This effectiveness could be explained on the one hand by the fact that these leaves would have acted as films over the grains, thus preventing any recovery of moisture, then on the other hand by the insecticidal and / or insect repellent properties of these leaves. Which would be due to the release ofbioactive molecules contained in their essential oils (Tia, 2012; Brou, 2013). Our observations are in agreement with the work published by Niamketchi *et al*. (2016) in Côte d'Ivoire. These authors have shown the effectiveness of the leaves of *Lippia multiflora* and *Hyptis suaveolens* in different proportions for the conservation of the nutritional quality of corn stored in granaries. These observations are therefore in agreement with the conclusions of the work of Fofana *et al.* (2018) who showed that adding the dried leaves of *Lippia multiflora* to triple bagging systems allowed the nutritional quality of cowpea seeds to be preserved for 8 months.

Experimental analysis shows that the quality of the corn kernels is preserved for 18 months in triple bagging systems with 2.5% biopesticides (20% of *Lippia multiflora* leaves and 80% of *Hyptis suaveolens* leaves). Under these conditions mentioned above, the experimental results are very close to those predicted, hence the validation of the mathematical model of the experiment. Indeed, according to Koffi *et al.* (2015) then Konan *et al.* (2016) such results would imply a high degree of fidelity between the values observed in the experiment and those predicted by the regression model.

V. CONCLUSION

This study made it possible to determine the ideal conditions for efficient storage from a central composite design in order to guarantee better lipid quality of the grains for industrial purposes. Our results confirm the importance of triple bagging for the conservation of grain corn. This technique prolongs the storage time while keeping the alteration parameters of lipid quality stable. This study also shows that the addition of the leaves of *Lippia multiflora* and *Hyptis suaveolens*, as a biopesticide, further extends the shelf life of grains in Côte d'Ivoire. It effectively preserves the lipid quality of the grains against oxidative and hydrolytic rancidity. The ideal storage conditions obtained are 2.5% as the minimum effective concentration of biopesticides (20% of leaves of *Lippia multiflora* and 80% of leaves of *Hyptis suaveolens*) for a period of eighteen months. Thus, the triple bagging methodology using the leaves of *Lippia multiflora* and *Hyptis suaveolens* as biopesticides in this study is accessible to the various players in the corn sector in Côte d'Ivoire. However, the study deserves to be deepened to follow the evolution of the physico-chemical parameters of the oil from the grains during the conservation in these storage systems.

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Special Types of Heat Exchangers

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***Abstract*— *The article describes the results of experimental research of a new type of heat exchangers in which the heat transfer surface consists of smooth polypropylene fibres with the outer fibre diameter of 0.5 mm and the total heat transfer surface area of 0.14 m^2. The research output is the information on the value of the heat transfer coefficient, exchanger heat capacity and pressure loss. This type of heat exchangers is contemplated for applications in areas where high chemical resistance of the equipment is required, as well as a relatively low weight and price and excellent resistance to the formation of wall deposits.*

***Keywords*— heat exchangers, polypropylene fibres, structure.**

I. INTRODUCTION

Within the new approach to the heat exchanger structure, the heat transfer surface consists of polypropylene fibres with an absolutely smooth and gas-proof surface or a surface with porous walls. The polypropylene fibres, which form plastic capillaries of exchangers, currently seem to be a very simple and cost-efficient component to be used in the structure of heat exchangers. Table 1 contains the technical parameters of a bundle of plastic capillaries which has been subjected to the experimental investigation. The purpose of the investigation was to identify the cooling capacity of the exchanger, but primarily the heat transfer coefficient of the transfer of heat from water in a polypropylene capillary to water in the surrounding environment.

TABLE 1
TECHNICAL PARAMETERS OF THE INVESTIGATED BUNDLE OD CAPILLARIES

Capillary material	Polypropylene
Potting material	Polyurethane
Number of capillaries	300 pieces
Length of capillaries	300 mm
Inner diameter of capillaries	0.42 mm
Outer diameter of capillaries	0.5 mm
Heat transfer surface area in the exchanger	0.14 m^2

Heat exchangers consisting of polypropylene fibres must meet certain requirements in terms of the pressure of the medium inside the capillaries p_{in} and on their outer wall p_{out}. The "*burst*" pressure is the maximum over pressure inside the capillaries relative to the external pressure at which the capillary wall bursts [1]. Its maximum value was identified experimentally as $4 \cdot 10^5$ Pa. The *"collapse*" pressure is the overpressure from the outer wall of the capillary against the inner wall, at which the fibre wall collapses with the subsequent reduction of its flow cross-section. The maximum value of such pressure was $2 \cdot 10^5$ Pa. The maximum operating temperature of the exchangers made of polypropylene fibres was 70 °C.

II. STRUCTURE DESCRIPTION

The new generation of heat exchangers, which are made of polypropylene fibres, uses hollow fibres while their ends are potted into a polyurethane tube. The fibres may be regarded as capillaries, and by potting them into the tube it is possible to create a whole bundle of capillaries (Fig. 1). The Figure shows one of the ends of such bundle. The part of the tube where the plastic capillaries are potted into the PVC tube is referred to as the *potting* [2]. Fig. 2 shows that the capillary diameters vary and they also vary along the capillary length. This is caused by the capillary manufacturing technology.

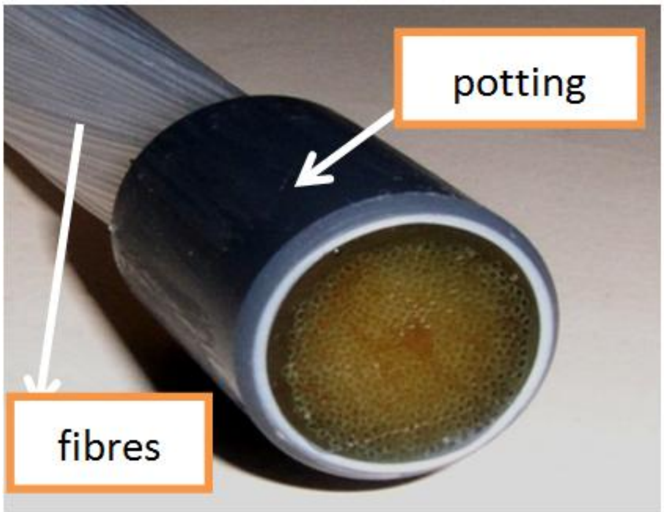

FIGURE 1: Fibres sealed in the potting

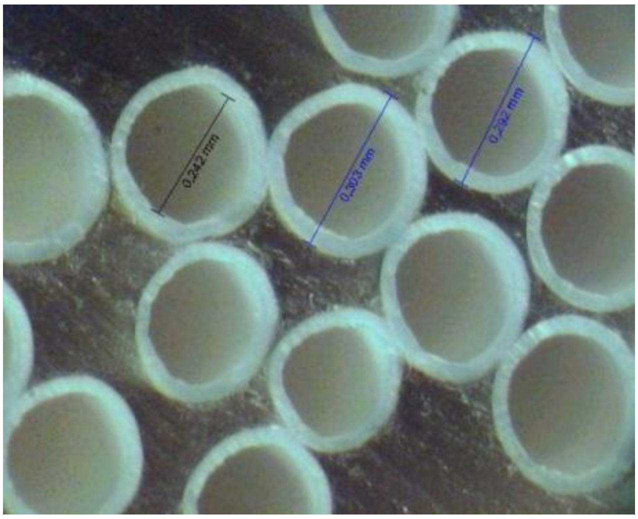

FIGURE 2: A detailed image of the fibres

The number of capillaries in a single working bundle may vary. In the version shown in Fig. 3, the PVC tube with the diameter of 50 mm may contain 300 to 1,500 pieces. The number of fibres potted into a PVC tube depends primarily on their outer diameters. A bundle with the outer fibre diameter of approximately 0.5 mm contains about 300 capillaries in the bundle, and with the diameter of 0.18 mm as much as 1,500 pieces. Generally, fibres may be more than 1 m long. However, their length is limited by the pressure loss of the bundle determined by its structure and strength. The length, outer fibre diameter and the number of fibres also determine the area of the heat transfer surface which in real operations ranges from 0.1 m^2 to 1.5 m^2. Fig. 3 shows the bundle of capillaries made by potting the fibres into the end of a transparent PVC tube. Such bundles are installed into heat exchangers used in counter flow Tube and Shell exchangers (Fig. 4). The red arrow indicates the flow of heated water in fibres which is supplied into the exchanger, and the blue arrows indicate the flow of the cooled medium.

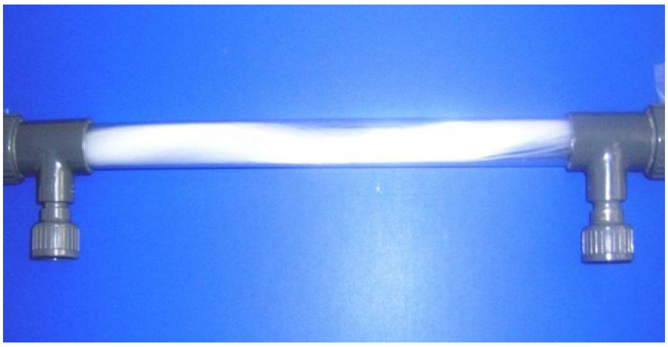

FIGURE 3: The bundle of fibres in a transparent tube

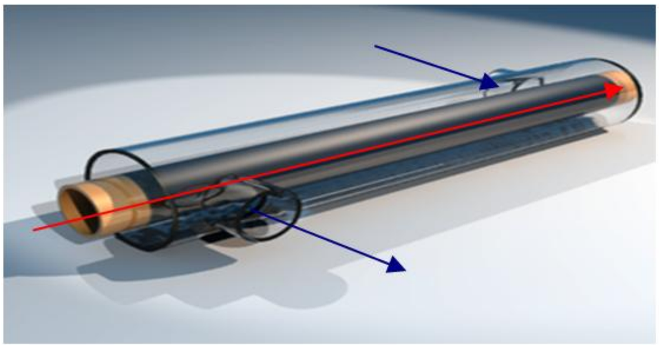

FIGURE 4: The Tube and Shell exchanger

The analysis of the heat exchanger made of polypropylene fibres comprised the assessment of the *fibre stretching degree*; it may also be referred to as the *fibre loosening degree*. In the "active" mode of the exchanger, at 0 % fibres loosening the fibres were assumed to be stretched slightly and in the same degree. For example, at the bundle length of 700 mm and the 6 % fibre loosening, which corresponded to 42 mm of the length of a fibre itself, the fibres were absolutely free and moved by water flowing around them in the entire dedicated space. The fibres were irregularly oscillating and this contributed to an increase in turbulence and subsequently to an increase in the heat transfer coefficient and specific thermal capacity of the heat exchanger.

Another parameter subjected to examination in exchangers made of polypropylene fibres was the *surface of fibres* as such. The test specimen of the heat exchanger described above was subjected to measurements using the fibres with absolutely smooth surfaces. Porous fibres are hydrophobic, but not gas-proof. Fig. 5 shows the surface of a porous fibre, and Fig. 6 shows the surface of a smooth fibre used in the test heat exchanger.

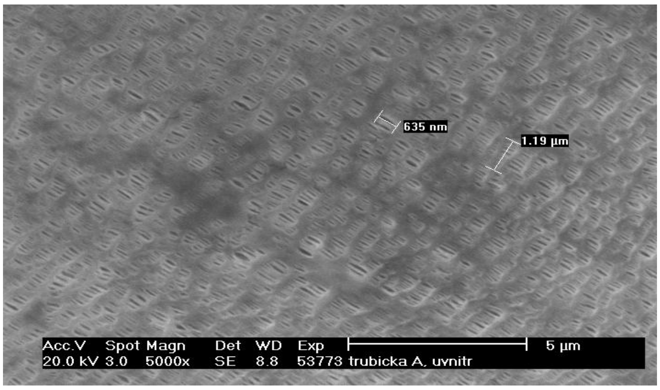

FIGURE 5: Porous fibre surface

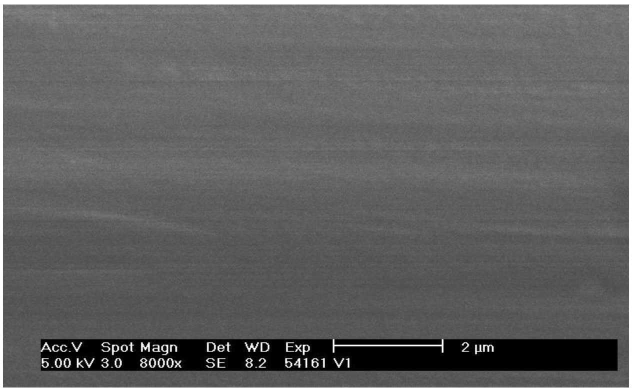

FIGURE 6: Smooth fibre surface

III. EXPERIMENTAL RESEARCH RESULTS

The experimental research was carried out with a compact exchanger with polypropylene fibres of the inner diameter of 0.5 mm. The number of potted fibres in one bundle was 300 fibres. The tube into which the fibre ends were potted was made of PVC and its diameter was 20 mm. Fig. 7 shows the inlet and outlet positions of the medium (water) supplied to the exchanger (positions 1–2: inlet and outlet of the heated medium; positions 2–3: inlet and outlet of the cooled medium). The distance between the point where water enters the exchanger and the point where it leaves the exchanger was 300 mm. The heat transfer surface area of the bundle of fibres was approximately 0.14 m^2.

At constant volumetric flow rate of water $Q_{V,\mathrm{out}}$ = 270 l·h^{-1}on the outer side of polypropylene fibres (0.075 kg·s^{-1}), the thermal capacity of the exchanger was monitored for three different mass flow rates of water flowing through polypropylene fibres. The flow rate values were 0.042 kg·s^{-1}; 0.083 kg·s^{-1}; and 0.125 kg·s^{-1} (alternatively expressed as volumetric flow rates, the values were 150 l·h^{-1}; 300 l·h^{-1}; and 450 l·h^{-1}). The obtained data on the heat transfer coefficient, one of the key indicators of heat transfer intensity, as well as on the pressure loss in the bundle of polypropylene fibres and individual mass flow rates are represented in Fig. 8. Maximum thermal capacity achieved during the experiment was approximately 4,400 W and it was identified using the following formula (1).

$$P = k \cdot \overline{\Delta T} \cdot S = Q_{m2} \cdot c_p \cdot \left(T_2^{''} - T_2^{'}\right) \qquad \mathrm{(W)} \tag{1}$$

Where k is the heat transfer coefficient (W·m^{-2}·K^{-1}); $\overline{\Delta T}$is the mean temperature difference (K); Q_{m2} is the mass flow rate of water in the secondary circuit (kg·s^{-1}); c_p is the specific thermal capacity of water (J·kg^{-1}·K^{-1}); and S is the heat transfer surface area (m^2).

Using the measured values, formula (1) was used to identify the heat transfer coefficient. In general, the following applies:

$$k = \frac{Q_{m2} \cdot c_p \cdot (T_2^{''} - T_2^{'})}{\overline{\Delta T} \cdot S} \, (\mathrm{W \cdot m^{-2} \cdot K^{-1}}) \tag{2}$$

For the counter flow heat exchanger, the mean temperature difference was calculated using the following formula (3):

$$\overline{\Delta T} = \frac{(T_1^{'} - T_2^{''}) - (T_1^{''} - T_2^{'})}{\ln \frac{T_1^{'} - T_2^{''}}{T_1^{''} - T_2^{'}}} \tag{3}$$

The maximum value of heat transfer coefficient, calculated using the thermal capacity at 450 l·h^{-1}, represented approximately 1,700 W·m^{-2}·K^{-1}. The pressure loss in polypropylene tubes (Δp_{in}), identified experimentally at the above specified flow rate, amounted to approximately 1.5·10^5 Pa, and the pressure loss measured at the outer side of tubes (Δp_{out}) was approximately 0.21·10^5 Pa.

Fig. 8 presents the graph containing all examined parameters in three different steady states. At the volumetric flow rate of 300 l·h^{-1}, the mean value of heat transfer coefficient was 1,620 W·m^{-2}·K^{-1}, and the total pressure loss was 0.95·10^5 Pa. At the flow rate of 150 l·h^{-1}, the pressure loss was 0.4·10^5 Pa, and the heat transfer coefficient was approximately 1,450 W·m^{-2}·K^{-1}.

Reduction of pressure loss in this type of exchangers requires either increasing the number of fibres in the bundle, or increase the inner diameter of fibres. A larger inner diameter of fibres would result in a decrease in the total heat transfer surface area and an increase in the dimensions of the exchanger, provided that the cooling capacity remains the same. It is at the designer's discretion to choose the optimal method of exchanger adaptation to a particular type of real operation or facility as well as the reasons of such choice.

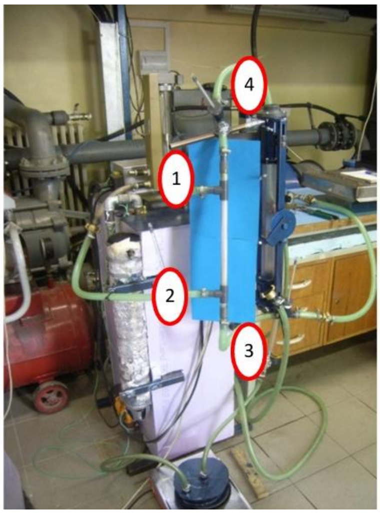

FIGURE 7: An image of the test equipment

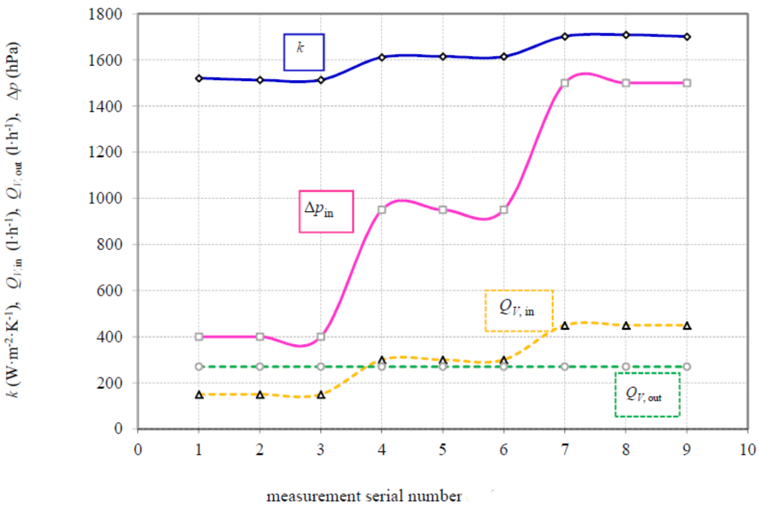

FIGURE 8: Measurement results

IV. CONCLUSION

At present, real technical operations lack a heat exchanger made of polypropylene which would offer strength and heat-transfer properties similar to those of metal exchangers while exhibiting excellent chemical resistance, relatively low weight and price, and resistance to the formation of wall deposits [3, 4].

The current increased interest in the use of propylene fibres for heat-transfer surfaces may be explained mainly by chemical stability of such heat-transfer surfaces, their resistance to corrosion and self-cleaning capacity. This facilitates the use of fibre bundles in operations where the use of conventional exchangers is impossible. Therefore, it provides a possibility to recover the residual thermal energy for example from waste waters. Such considerations are in favour of the use of exchangers made of polypropylene fibres, which will only be possible under certain conditions. It is also obvious that the use of such exchangers will be limited by their resistance to heat and pressure, or by their strength. Very thin fibres require proper balance between mechanical and operating parameters. Designing such exchangers require the application of the correct correlation between the fibre wall thickness, maximum pressure loss and heat transfer coefficient.

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