

Effect of Incorporating *Parkia Biglobosa* Pulp on the Sensory Characteristics of Stirred Yoghurt

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Abstract

Parkia biglobosa, called African locust bean in English, is a non-wood forest product that provides a pulp with good nutritional qualities. Consumed in its raw state, the pulp is generally not processed in any way. With this in mind, the pulp was incorporated into yoghurt at levels of 2%, 4%, 6%, and 10% (note that a control yoghurt without pulp was prepared). A hedonic test was also carried out on a panel of 63 people to assess the acceptability of the yogurts designed on a rating scale of 1 to 9. Interpretation based on the average of sensory attributes (colour, smell, appearance, texture and taste) showed that yogurts Y1 (0% pulp), Y3 (4% pulp) and Y4 (6% pulp) were better than yogurts Y2 (2% pulp) and Y5 (10% pulp). In order to optimise the processing of sensory data, the validity of the one-factor ANOVA was studied. The study revealed that the ANOVA was invalid and that a non-parametric test (Kruskal-Wallis) enabled the sensory data to be processed correctly. The Kruskal-Wallis test showed that no significant difference was detected in terms of appearance, texture, and taste between yoghurt Y1 and yoghurt Y3. However, there was a significant difference in colour and odour between Y1 and Y3, even though the panellists found Y3 pleasant in terms of colour and odour. Statistical analysis, principal component analysis (PCA), and the hedonic profile established on the basis of this experiment indicate that the incorporation rate of 4% African locust bean pulp represents the ideal rate since the appreciability of the organoleptic criteria of Y1 is almost similar to that of Y3.

Keywords

Parkia biglobosa; pulp; yoghurt; hedonic test; sensory data and attributes

Introduction

Yoghurt is a coagulated dairy product that is increasingly combined with fruit pulps such as strawberry, papaya, mango, etc., in order to increase its nutritional potential and improve its organoleptic characteristics [1-5]. To this end, *Parkia biglobosa* pulp, which is rich in sugar, β -carotene, and minerals (Ca, K, and Mg) [6, 7], has been incorporated into yoghurt at increasing rates (2%, 4%, 6%, and 10%). *Parkia biglobosa*, also known as the African Locust bean tree, is a deciduous plant that can reach a height of 20 m and whose resources are used for food purposes [8, 9]. The fruit of the African locust bean comes in the form of long pods containing seeds coated in yellow pulp [10]. The seeds are also fermented to make a condiment that enhances the flavour of many food preparations [11-13]. Despite its interesting nutritional qualities, the pulp is generally consumed in its raw state without any processing [14]. This is the case for many non-wood forest product resources that are nutritionally rich and not processed on an industrial scale [15]. In order to make the most of this pulp and give consumers the benefit of the nutrients that are endogenous to it, its incorporation into yoghurt was envisaged.

When the pulp is added to the yoghurt, a sensory analysis, in particular the hedonic test, is carried out to assess the degree of acceptability of the yoghurts produced.

1. Materials and methods

1.1 Raw material

Ripe *Parkia biglobosa* fruits (Figure 1) were harvested in July 2024 in Sédhiou (12°42'17.0 'N 15°33'22.4 'W), Senegal. After drying the fruit, the pulp was extracted by hulling the healthy fruit and then manually using a mortar fitted with a pestle. The pulp was then stored in airtight packaging.



Figure 1. *Parkia biglobosa* fruit (a) and pulp (b).

1.2 Yoghurt production

Stirred yoghurt with 25% dry matter was produced according to the steps described in Figure 2.

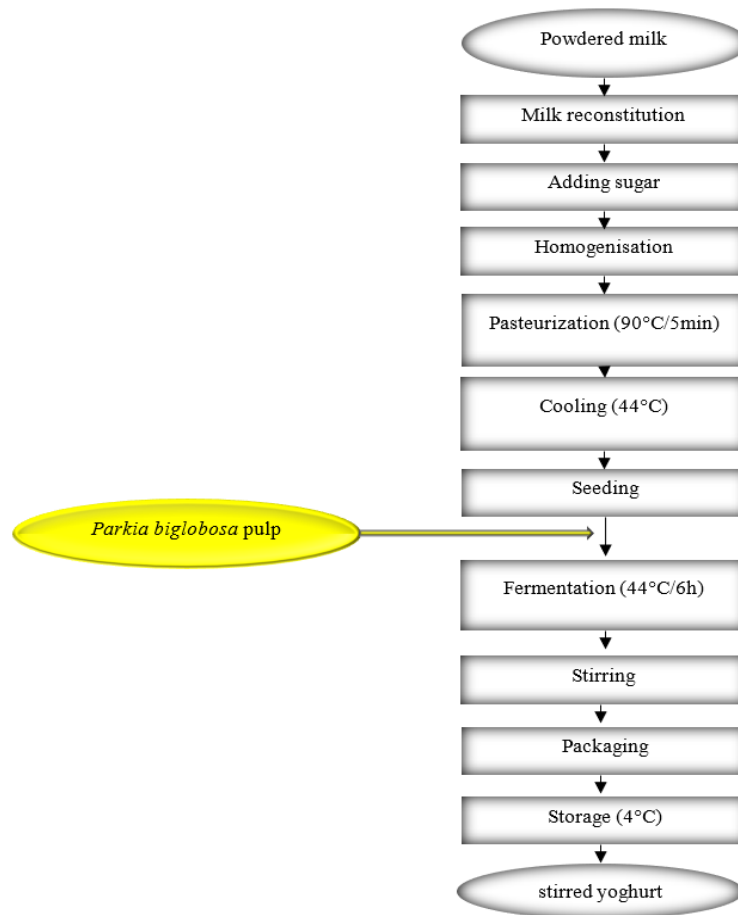


Figure 2. Production diagram for stirred yoghurt [16].

A control stirred yoghurt (Figure 3) in which no *Parkia biglobosa* pulp was added was produced. Table 1 shows the different yoghurts prepared with different rates of incorporation of African locust bean pulp.

Table 1. Incorporation rate of African locust bean powder in yoghurt

Yoghurts	Y1	Y2	Y3	Y4	Y5
Incorporation rate	0%	2%	4%	6%	10%

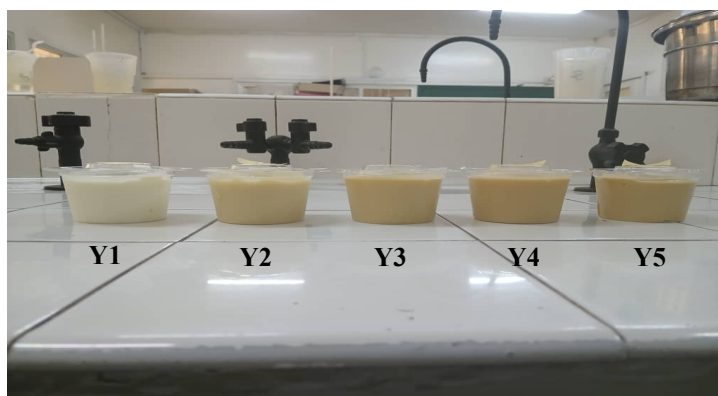


Figure 3. Yoghurts were produced for sensory evaluation.

1.3 Physico-chemical analyses

After preparation of the yoghurts, the colour was determined using a Konica Minolta colorimeter. The pH and acidity were determined using a Hanna Instruments HI2209-01 pH meter and a 0.1 N sodium hydroxide solution, respectively. The Atago PAL-alpha refractometer was used to determine the dry matter or Brix of the yoghurts.

1.4 Hedonic test

In order to evaluate the degree of appreciation of yoghurts, a hedonic test was carried out on a panel of 63 people [17]. The parameters (colour, smell, appearance, texture, and taste) were evaluated on a scale of 1 to 9, ranging from extremely unpleasant to extremely pleasant. It should also be noted that appearance indicates whether the yoghurt is liquid or firm, and texture refers to the homogeneity or presence of lumps in the yoghurt. The yoghurt samples, packaged in disposable 100g pots and coded with three random numbers, were presented simultaneously to the tasters, who could taste them at will and who rinsed their mouths with water before moving from one sample to another [18].

1.5 Statistical analysis

These were performed using XLSTAT software version 2021.2.2. This software was used to study the validity of the one-factor ANOVA. If the ANOVA is invalid, a non-parametric test (Kruskal-Wallis) will be used to detect significant differences between the sensory data of the yoghurt samples. Principal component analysis (PCA) was also established to identify the correlation between the samples and the variables.

1.5.1 Validity testing

1.5.1.1 ANOVA

To highlight the validity of the one-factor ANOVA, the normality test combined with the homoscedasticity test is used. ANOVA is valid provided that the samples are independent, the residuals follow a normal distribution, and the variances of the samples are equal (homoscedasticity) [19]. For the normality test, two hypotheses (H_0 and H_a) are defined. H_0 indicates that the residuals follow a normal distribution, and H_a indicates that the residuals do not follow a normal distribution. If the calculated p-value is less than the significance level $\alpha=0.05$, the alternative hypothesis H_a is chosen. As for the homoscedasticity test, H_0 and H_a indicate, respectively, that the residuals are homoscedastic or the residuals are heteroscedastic. If the calculated p-value is less than the significance level $\alpha=0.05$, the alternative hypothesis H_a is chosen. Following the two tests (normality of the residuals and homoscedasticity), if H_a is retained, then the ANOVA is invalid [20].

1.5.1.2 Kruskal-Wallis

An alternative to one-way ANOVA, Kruskal-Wallis is a non-parametric test for processing data when ANOVA is invalid

[21]. The hypotheses H_0 and H_a are used and are defined:

H_0 : The samples come from the same population

H_a : Samples come from different populations

If the calculated p-value is less than the significance level $\alpha=0.05$, the null hypothesis H_0 must be rejected, and the alternative hypothesis H_a retained. In this case, the Kruskal-Wallis test can be used to detect significant differences in the sensory data [22]. The Dunn test (pairwise comparison test) will locate pairs of samples that differ significantly.

2. Results and discussion

2.1 Physico-chemical analyses

Table 2 shows the results of physico-chemical analyses of yoghurts:

Table 2. Initial physico-chemical parameters of yoghurts

Yoghurts	Y1	Y2	Y3	Y4	Y5
L	92.025 ^a	77.135 ^b	73.570 ^c	69.880 ^d	69.595 ^e
a	-3.675 ^a	-2.440 ^b	0.085 ^c	1.860 ^d	2.960 ^e
b	14.735 ^a	27.110 ^b	33.855 ^c	36.250 ^d	37.730 ^e
IJ	21.790 ^a	42.495 ^b	52.330 ^c	56.870 ^d	58.705 ^e
pH	5.325 ^a	5.265 ^b	5.280 ^b	5.445 ^c	5.895 ^d
Acidity (mEq/100g)	3.515 ^a	3.860 ^b	3.894 ^b	3.799 ^b	3.147 ^c
Brix	21.050 ^a	22.000 ^b	22.800 ^c	24.450 ^d	27.900 ^e

Statistical analysis (one-way ANOVA) of Table 2 shows that the colour parameters (L, a, b, and IJ) vary significantly with increasing incorporation rate. With the exception of lightness (L), a, b, and IJ increase with the addition of African locust bean pulp. In fact, the pulp colours the yoghurt yellow, and this yellow colouring becomes more pronounced as the pulp is incorporated into the yoghurt (Figure 4). Brix evolves in the same way (increase) as a, b, and IJ. What's more, the pulp is very sweet, hence the increase in dry matter [6]. Compared with the pH of yoghurt Y1 (0% pulp), a decrease in pH is observed when the incorporation rate varies between 2 and 4% and when the pH increases from 6 to 10%. The pH of the pulp is slightly acidic (pH = 5 [6, 23]), which leads to a change in the pH of the yoghurt. Acidity is inversely proportional to pH, which is why it increases when the addition of pulp varies from 2 to 4% and decreases from 6 to 10% of the addition.

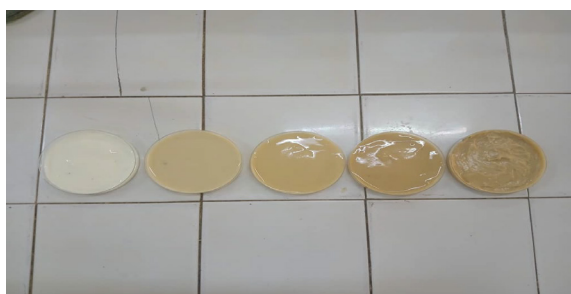


Figure 4. Change in colour with increasing addition of pulp.

2.2 Results of the hedonic test

Table 3 gives the average results for each parameter on the basis of a rating scale from 1 to 9.

Averaging the scores given to each sensory characteristic (Table 3), yoghurts Y1 ($7.88 \approx 8$) and Y3 ($7.14 \approx 7$) are considered very pleasant and pleasant, respectively, by the tasters. Y4 is considered quite pleasant. However, in relation to their sensory perception of Y2 and Y5 yogurts, consumers are rather indifferent. Regarding the acceptability of colour, the panellists gave a score of 8 to the colour of Y1 yoghurt, which corresponds to yoghurt without African locust bean powder. The tasters therefore considered the colour of Y1 yoghurt to be a very pleasant colour. On the other hand, Y2

(5.73 $\approx$ 6) and Y4 (6.21 $\approx$ 6) have a colour rating associated with being fairly pleasant. In addition, Y3 (6.87 $\approx$ 7) has a colour acceptability score corresponding to pleasant, while Y5 (5.22 $\approx$ 5) has a score equivalent to neither pleasant nor unpleasant. Based on this analysis, tasters liked the colour of plain yoghurt (Y1) more. Nevertheless, the colour of Y3 yoghurt was very well appreciated. It should be noted that in terms of appreciation of the colour of yoghurts with the presence of African locust bean pulp, an incorporation rate of 4% is the optimum rate, since below or above 4%, the colour is less appreciated by tasters. With regard to the degree of acceptability of the smell, yoghurt Y1 is more appreciated (7.68 $\approx$ 8). However, Y3 (6.90 $\approx$ 7) gets a rating for the smell deemed pleasant. Yoghurts Y2 (6.16 $\approx$ 6), Y4 (6.11 $\approx$ 6), and Y5 (5.63 $\approx$ 6) score the odour associated with the mention as quite pleasant. In relation to the acceptability of the appearance of the yoghurts, Y1 (7.70 $\approx$ 8) and Y3 (7.27 $\approx$ 7) are rated as very pleasant and pleasant, respectively. However, yoghurts Y2 (4.27 $\approx$ 4) and Y5 (4.48 $\approx$ 4) are considered rather unpleasant in terms of appearance. Thus, an incorporation of less than or greater than 4% proves to be less appreciated by tasters on the basis of appearance (Table 3). In terms of texture acceptability, the results in Table 3 reveal that the texture of yoghurts Y1 (8.03 $\approx$ 8) and Y3 (7.4 $\approx$ 7) is judged very pleasant and pleasant, respectively, by the panelists. The texture of yoghurt Y2 (4.17 $\approx$ 4) is less appreciated and is associated with the mention rather unpleasant. In terms of liking the taste of the yoghurts, Y1 (7.97 $\approx$ 8) and Y3(7.24 $\approx$ 7) have a taste associated with the mention as very pleasant and pleasant, respectively. Nevertheless, in relation to their taste perception, Y2 (5.03 $\approx$ 5) leaves the panellists indifferent. At the end of this analysis based on the average, yogurts Y1 and Y3 are considered at least pleasant on all sensory criteria. Yoghurt Y4 proved to be fairly pleasant, while Y2 and Y5 left tasters indifferent. On the basis of these results, the incorporation rate of 4% seems to be the optimum rate for adding *Parkia biglobosa* pulp to yoghurt.

Table 3. Sensory data from the hedonic test

Yoghurts	Codes	Colour	Smell	Appearance	Texture	Taste	Average
Y1	123	8.00	7.68	7.70	8.03	7.97	7.88
Y2	456	5.73	6.16	4.27	4.17	5.03	5.07
Y3	789	6.87	6.90	7.27	7.40	7.24	7.14
Y4	004	6.21	6.11	6.40	6.30	6.60	6.32
Y5	315	5.22	5.63	4.48	5.06	5.90	5.26

2.3 Statistical analysis

2.3.1 ANOVA hypothesis testing

In order to ensure optimal processing of the yoghurt sensory data, the validity of the ANOVA was verified.

2.3.1.1 Residual normality test

Figure 5 shows the results of the residual normality test:

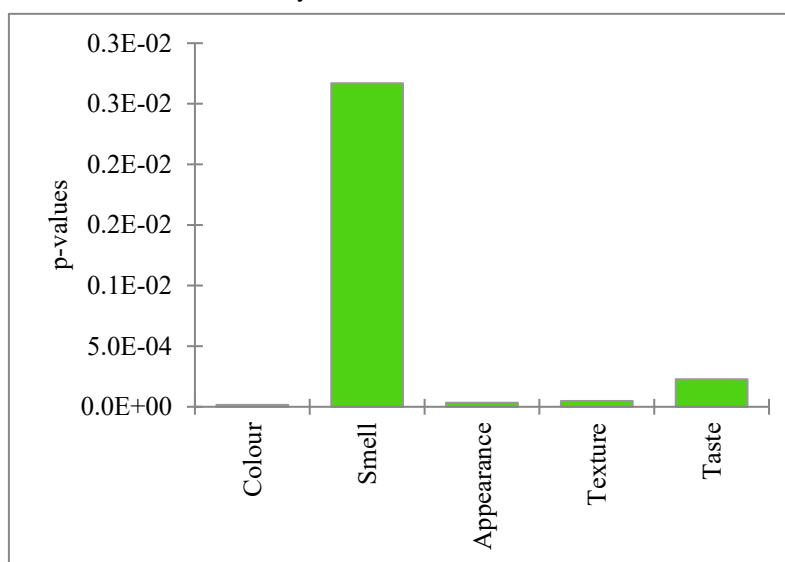


Figure 5. Summary of normality tests for all dependent variables.

Figure 5 shows that for all the parameters (colour, smell, appearance, texture, and taste), the p-value is less than $\alpha = 0.05$, so the residuals do not follow a normal distribution. H_a is therefore retained.

2.3.1.2 Residual homoscedasticity test

Table 4 shows the results of the residual homoscedasticity test.

Table 4. Homoscedasticity test of residuals

Parameters		Colour	Smell	Appearance	Texture	Taste
Yoghurts	p-value	<0.0001	0.032	0.003	0.001	<0.0001
	Hypothesis retained	H_a	H_a	H_a	H_a	H_a

Table 4 shows the heteroscedasticity of the residuals. H_a is retained, so the residuals are not homoscedastic. The results in Figure 5 and Table 4 indicate that the one-factor ANOVA is invalid. For a better treatment of the sensory data, the non-parametric test should be used.

2.3.2 Non-parametric test (Kruskal-Wallis)

Having noted the invalidity of ANOVA, the Kruskal-Wallis test, an alternative to one-factor ANOVA, was used for a good statistical analysis of sensory information.

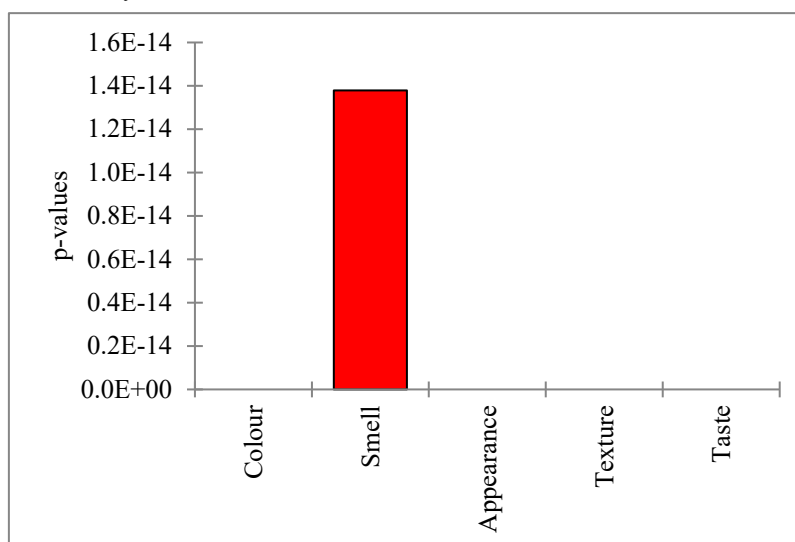


Figure 6. p-values (Kruskal-Wallis) as a function of the variables.

The analysis of Figure 6 shows that the p-value is less than 0.05 on all sensory parameters. Therefore, H_a , indicating that the samples come from different populations, is retained. The results of Figure 6 reveal that a significant difference exists between the samples on all sensory criteria and that the Dunn test with Bonferroni correction must be used to identify the level of significance between the yogurt samples.

2.3.2.1 Dunn's test associated with Bonferroni correction

Since the Kruskal-Wallis test identified significant differences between samples for all criteria, the Dunn's test associated with Bonferroni correction is used to locate the pairs of significantly different samples. The results are reported in Table 5:

Table 5. Dunn's test combined with Bonferroni's correction on yoghurts

Samples	Number	Sum of ranks	Average of ranks	Colour	
				Groups	
Y1	63	15455.000	245.317	A	
Y3	63	11236.000	178.349	B	
Y4	63	8916.500	141.532	B	C

Table 5 Continued

Y2	63	7566.000	120.095		C
Y5	63	6596.500	104.706		C
Smell					
Samples	Number	Sum of ranks	Average of ranks	Groups	
Y1	63	14280.500	226.675	A	
Y3	63	11380.000	180.635		B
Y2	63	8629.500	136.976		B C
Y4	63	8494.500	134.833		C
Y5	63	6985.500	110.881		C
Appearance					
Samples	Number	Sum of ranks	Average of ranks	Groups	
Y1	63	14603.500	231.802	A	
Y3	63	13163.500	208.944	A	B
Y4	63	10704.500	169.913		B
Y5	63	5937.000	94.238		C
Y2	63	5361.500	85.103		C
Texture					
Samples	Number	Sum of ranks	Average of ranks	Groups	
Y1	63	15122.500	240.040	A	
Y3	63	13050.500	207.151	A	
Y4	63	9961.000	158.111		B
Y5	63	6833.500	108.468		C
Y2	63	4802.500	76.230		C
Continued					
Samples	Number	Sum of ranks	Average of ranks	Groups	
Y1	63	14299.500	226.976	A	
Y3	63	11797.500	187.262	A	B
Y4	63	9873.000	156.714		B C
Y5	63	8061.000	127.952		C D
Y2	63	5739.000	91.095		D

There is therefore a significant difference in all sensory parameters. Indeed, concerning the degree of appreciation of the color of the yogurts, Y1 is significantly different from Y2, Y3, Y4, and Y5. However, there is no significant difference between Y3 and Y4. In addition, Y2, Y4, and Y5 are in the same group, so these yogurts are statistically homogeneous in terms of appreciation of the color. It should be noted that the level of acceptability of the color of Y3 is significantly different from that of the colors of Y2 and Y5. The addition of African locust bean pulp changes the color of the yogurt to a yellow tint. This yellow coloring becomes more pronounced as the incorporation rate increases. This significant difference in terms of color appreciation is explained by the fact that the tasters opt for a plain yogurt (Y1), a yogurt usually consumed. However, the color of yogurt Y3 (4% incorporation) is considered pleasant (Table 3). Regarding the degree of acceptance of the odor, the statistical analysis gives the same results as those of the color. This reveals that, from a statistical point of view, the odor of yogurts is appreciated in the same way as the color. From this statistical

analysis, it should be noted that depending on the acceptability of the odor, Y1 is different from Y2, Y3, Y4, and Y5. Despite the tasters' orientation towards yoghurt Y1, yoghurt Y3 had an odour described as pleasant (Table 3). In terms of the acceptability of the appearance of the yoghurts, Y1 and Y3 were statistically homogeneous. However, there was a significant difference between yogurts Y1, Y2, Y4, and Y5. Finally, according to the statistical analysis of appearance, yoghurt Y1 (without pulp) is appreciated as much as yoghurt Y3 (4% incorporation). In terms of texture, there was no significant difference between Y1 and Y3, which were nevertheless statistically different from Y2, Y4, and Y5. The tasters appreciated the texture and appearance of Y1 and Y3 yogurts in the same way. As for the taste of the yogurts, no significant difference was detected between the tastes of Y1 and Y3. However, Y1 was statistically different from Y2, Y4, and Y5. It should also be noted that Y3 and Y4 are in the same group, as are Y4 and Y5, as well as Y5 and Y2. The Kruskal-Wallis test did not detect a statistical difference between yogurts belonging to the same group. It should be noted that the statistical analysis reveals that the taste of yoghurt Y1 is as much appreciated as that of yoghurt Y3 by the tasters. At the end of the statistical analysis, Y1 and Y3 yogurts were very well appreciated by the panellists. No statistical difference was detected in terms of the acceptability of the appearance, texture, and taste of Y1 and Y3 yogurts. Despite a significant difference in the level of appreciation of colour and odour, consumers rated these two parameters of Y3 yoghurt as pleasant (Table 3). Based on these experimental data, the incorporation rate of 4% pulp seems to be ideal for the design of yoghurt with added *Parkia biglobosa* pulp.

2.3.3 Principal component analysis (PCA)

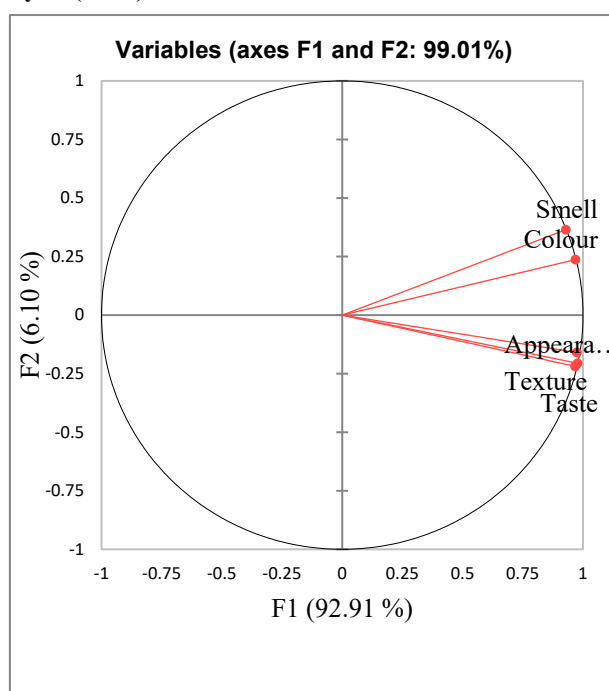


Figure 7. Correlation circle between sensory attributes.

Principal component analysis (PCA) allowed the establishment of the correlation graph between the sensory variables. The combination of the two factorial axes, F1 and F2, gives a variability of 99.01% (Figure 7). This means that the representation is of good quality. The F1 axis represents 92.91% of the initial information, while the F2 axis constitutes 6.10% of the initial information. Furthermore, the variables (odor, color, appearance, texture, and taste) are very well represented and are positively correlated. This could mean an overall consistency in the sensory assessments. The analysis of Figure 7 shows that all the sensory parameters are positively linked with the F1 axis. Therefore, the F1 axis can be the acceptability axis of the organoleptic characteristics of yogurts. It should be noted that the color and appearance are much closer to the F1 axis. It is likely that color and appearance have much more influence on the F1 axis than the other variables. This is equivalent to saying that yogurts with a color and appearance judged pleasant are also well appreciated in terms of texture, smell, and taste.

The correlation graph (Figure 8) between the sensory variables and the yoghurt samples reveals that Y2 and Y5 yoghurts are less appreciated in terms of colour, smell, texture, appearance, and taste. This shows that a 2% or 10% incorporation rate has a negative effect on the acceptability of the yoghurt's sensory characteristics. Yoghurt Y4 is better

appreciated than yoghurts Y2 and Y5 because it is closer to the sensory attributes. In fact, Y4 yoghurt corresponding to the 6% incorporation rate is considered quite pleasant by the panellists (Table 3). This graph shows that yogurts Y1 and Y3 are better than the others on all the sensory parameters. Figure 9 shows that in terms of appreciation of organoleptic parameters, the yoghurt samples are grouped into three classes: Y1 and Y3 share the same class (C1), Y2 and Y5 are in the same group (C2) and Y4 presents a different level of acceptance of sensory characteristics than the other yoghurts (C3). Figure 9, therefore, reveals that a rate of incorporation of 4% African carob pulp in the yoghurt is well appreciated by the tasters because yoghurt Y1 has the same level of appreciation as yoghurt Y3 (Y1 and Y3 are in the same class).

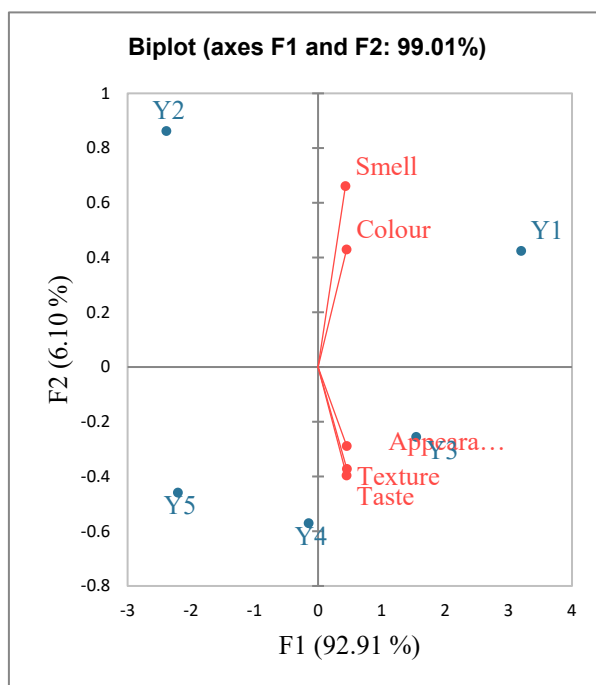


Figure 8. Correlation between sensory attributes and yoghurt samples.

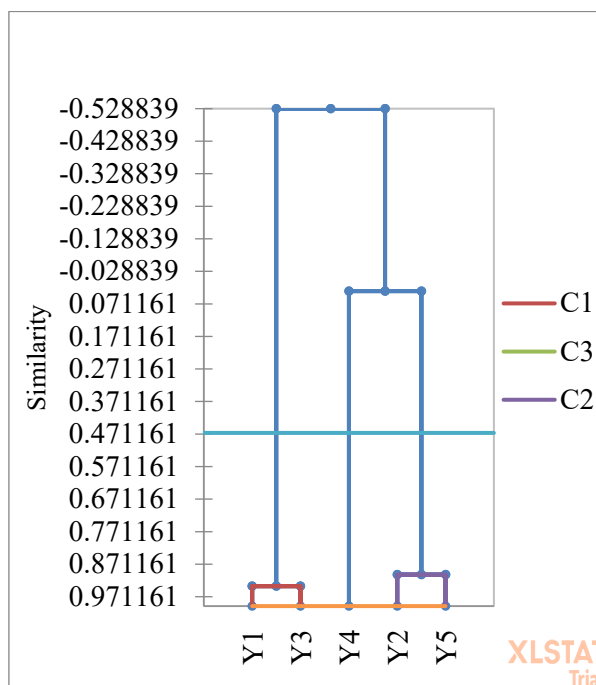


Figure 9. Hierarchical classification of yogurt samples.

2.3.4 Hedonic profile

The aim of the hedonic profile is to take into account consumer preferences and to compare the overall hedonic appreciation of the different yoghurt samples by focusing on the individual feelings linked to the pleasure or displeasure provoked by each yoghurt. Figure 10 shows that yogurts Y1 and Y3 are better on all sensory attributes (colour, smell, appearance, texture, and taste). Yoghurt Y2 is the least appreciated. This hedonic profile corroborates the results of the PCA to the extent that a 4% incorporation rate results in a yoghurt that is just as appreciated as the yoghurt without African locust bean pulp (Y1).

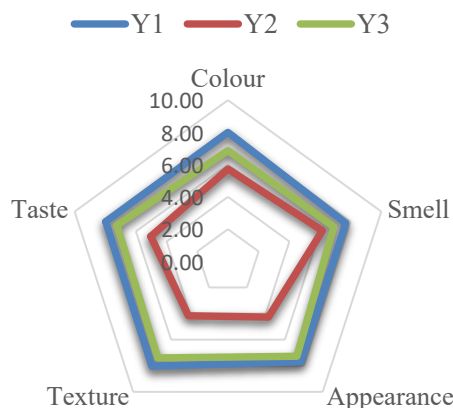


Figure 10. Hedonic profile of yogurts.

3. Conclusion

Yoghurt is a fermented dairy product that is widely consumed because of its interesting nutritional qualities. To increase its nutritional potential, fruit pulps are added to yoghurt, hence the incorporation of African locust bean pulp. Physico-chemical analysis shows that *Parkia biglobosa* pulp modifies the brix, colour parameters, and pH of the yoghurt. To determine the optimum incorporation rate, statistical analysis (Kruskal-Wallis), PCA, and the hedonic profile were used. They revealed that the incorporation rate of 4% was the best, since statistically, yoghurt Y3 (4%) was similar to yoghurt Y1 (0% pulp) in terms of appreciation of appearance, smell, and taste. Looking ahead, we need to determine the expiry date of yoghurts containing *Parkia* pulp by studying changes in physico-chemical and microbiological parameters during storage.

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