



Study of the Links Between the Physicochemical Parameters of Five Varieties of Mango (*Mangifera Indica*) Dried in Senegal

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Abstract

In Senegal, to combat the rotting of their produce, women working in GIEs (economic interest groups) have been processing mangoes into by-products for some years now. In this work, we studied the links between physico-chemical parameters following three drying techniques: one without treatment (normal) used by women processors, and two others with pre-treatment in a sugar solution of 350g/L concentration, then slightly heated for two and three hours, respectively. Proteins were quantified using the Kjeldahl method, sugars using the Luff-Schoorl method, and moisture content. The results of this study show that knowing one of the two indices (browning or yellowing) can accurately predict the other, but this link is not observed for the other variables. The quantities of sugars, proteins, and moisture vary according to variety and drying technique. According to the three drying techniques used, the Kt variety always has the highest quantities of protein, total sugars, and reducing sugars, and the lowest browning index. Knt is also rich in total sugars. The five varieties studied give interesting results compared with the literature.

Keywords

Mango (*Mangifera indica*); Drying; Sugars; Proteins; Moisture; Indices

1. Introduction

Post-harvest losses of mangoes are estimated at 36% in sub-Saharan Africa [1]. Several factors contribute to these high losses: lack of adequate storage and transport infrastructure, cold chain problems, unsuitable handling techniques, lack of training and awareness among growers, etc.

In Senegal, to deal with this problem, women working in GIEs (economic interest groups) have for some years been processing mango into by-products such as jams, nectar, juice, drying, etc. The storage of juice in rural areas is hampered by refrigeration problems. In such conditions, studies [2, 3] have shown that mango drying is an interesting option. Drying remains the most suitable activity in rural areas, simply because it can be preserved at room temperature and does not require cold conditioning or electricity [4]. In this study, we dried five varieties of mango, two for export (Kent and Keitt) and three for local consumption and national marketing. To carry out this work, we employed three drying techniques: the untreated (normal) drying technique used by the women of Casamance and two techniques with pre-treatment by soaking the mango slices in a sugar solution of 350g/L concentration, then heated for two hours for one and three hours for the other, according to the method of [5]. Color thus becomes the main attractive factor and the major attribute of its marketability according to consumers [6]. As a result, the nutritional quality of these products is not at the forefront of consumers' minds. This nutritional quality can be affected by many chemical factors (such as browning) during heat drying.

The objectives of this study are: to understand the relationship between physicochemical parameters such as

quantities of total sugars, reducing sugars, proteins, and yellowing and browning indices (indices). A better understanding of the links between these different physico-chemical parameters can help to improve the quality of dried products. Drying was carried out at Kandialan Diola (in the commune of Ziguinchor), a region where this activity is more widely practiced.

2. Methods and Materials

2.1 Materials

2.1.1 Samples

The mango samples were collected from an orchard in the village of Kaguitte in the Ziguinchor region, Oussouye department, a locality severely affected by post-school losses. Fifteen kilograms of each variety were harvested at commercial maturity and without injury. The mangoes were kept at the drying center until they reached the desired level of ripeness.



Figure 1. Mango rot in Casamance (village of Kaguitte 2019).

2.1.2 Drying equipment

The technology used is a natural convection gas dryer with forty-two racks. Dimensions Length (outside): 6.96 m; width (outside): 2.438 m; height (outside): 2.591 m. The dryer is accompanied by other equipment such as scales, plastic basins, peeling knives, gloves, mufflers, smocks, and so on. Drying time is twelve hours.



Figure 2. Dryer at Kandialan Diola (in the commune of Ziguinchor).

2.2 Methods

2.2.1 Drying stages

The mangoes are sorted, washed in drinking water, drained, and weighed. After peeling and pitting, the mangoes are sliced. The skins, pits, and pulp are weighed. For drying without pre-treatment, the slices are placed directly on the drying racks.

After pre-treatment, the slices are introduced into a sugar solution with a concentration equal to 350g/L, and the whole is heated for two and/or three hours. The slices are then placed on racks, leaving space between them. After drying, the slices are packed in bags using an air aspirator.



Figure 3. Mango slices are being processed, mango slices are on the rack, and bags of dried mangoes are being processed.

2.2.2 Physico-chemical analysis of various samples

2.2.2.1 Relative humidity and total solids content

Total solids were determined using aluminum or quart crucibles. The crucibles were oven-dried at $103 \pm 2^\circ\text{C}$ for 30 min, then cooled in a desiccator for 20-30 min and weighed. Five grams of dried mango were placed in the crucibles, then the whole was placed in an oven at $103 \pm 2^\circ\text{C}$ for 3h. The crucibles are cooled in a desiccator for 20-30 min, then weighed. The samples are returned to the oven for 1h, cooled, and weighed. Samples are returned to the oven for 30 min, cooled, and weighed until a constant mass is obtained.

2.2.2.2 Determination of nitrogen content and calculation of crude protein content

This European standard specifies a method for determining the nitrogen content of fruit and fruit juices using the Kjeldahl method, and a method for calculating the crude protein content. The method does not distinguish between protein and non-protein nitrogen.

Nitrogen content: quantity of nitrogen determined after application of the procedure described in this document. It is expressed as a percentage by mass of dry product.

Crude protein: quantity of crude protein obtained from the nitrogen content as determined by applying the method described herein, calculated by multiplying this content by an appropriate factor according to the type of cereal or legume. It is expressed as a percentage by mass of dry product. The nitrogen content, N, expressed as a percentage by mass of dry product, is obtained using the following equation:

$$N = \frac{(V_1 - V_0) \times T \times 0,014 \times 100}{m} \times \frac{100}{100 - H}$$

V_0 is the volume, in milliliters, of the sulfuric acid solution used for the blank test;

V_1 is the volume, in milliliters, of the sulfuric acid solution used for the test sample;

0.014 is the expression, in grams, of the quantity of nitrogen equivalent to the use of 1 ml of a sulfuric acid solution of normality 1 (0.5 mol/l);

T is the normality of the sulfuric acid solution used in the titration; m is the mass, in grams, of the test sample;

H is the water content.

Express the result to two decimal places.

Calculate the crude protein content of the dry product by multiplying the value obtained when determining the nitrogen content (11.1) by the conventional factor of 6.25, rounding off the result to one decimal place.

2.2.2.3 Total and reducing sugar contents

For reducing and total sugars, the Luff-Schoorl method is used after hydrolysis with HCl for 3 minutes boiling time. The sugar liquor is oxidized under heat by a cuproalkaline solution, and the excess cupro liquor is titrated iodometrically. At the same time, the cuproalkaline liquor is titrated.

The total sugar content, expressed in mg per 100 mL of product, is given by the equation:

$$\% \text{ reducing sugars} = m \times \frac{100}{25} \times d \times \frac{100}{V}$$

V: Test sample in milliliters (liquid sample);

V0: Volume of 0.1N thiosulfate solution used to titrate the blank;

V1: Volume of 0.1N thiosulfate solution used to titrate the sample;

m: mass of sugar, expressed in mg, corresponding to the volume difference between blank and sample (V0-V1).

d: dilution factor

3. Results and discussion

3.1 Relationship between reducing sugars, total sugars and proteins

The Maillard reaction occurs whenever reducing sugars (free carbonyl function) are in the presence of proteins, peptides, or amino acids (free amine function), and all the more easily at high temperatures, low water activity, and over long periods of time. Maillard's discovery in 1912 (Maillard, 1912) that the heating of amino acids and reducing sugars led to the formation of yellow-brown pigments highlighted the importance of amino groups in accelerating rearrangements in reducing sugars. This is a hot reaction between the carbonyl function of an ose and the amine function of a protein or amino acid. An imine is formed, which is rearranged (Amadori rearrangement) to form a ketone, which can then react with another amine function. This can lead to polymerization, resulting in brown products.

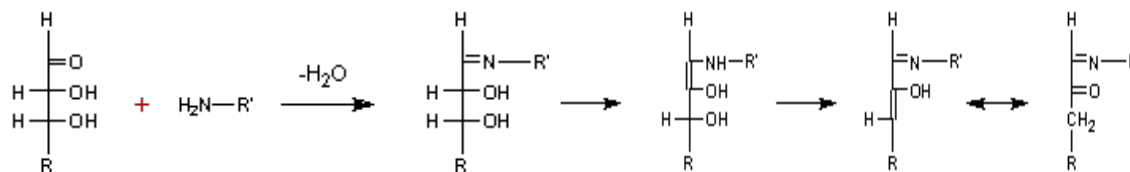


Figure 4. Schematic diagram of Amadori compound formation in the Maillard reaction between glucose and an amino compound [7].

Analyses are therefore carried out to understand the links between variations in various physicochemical parameters such as reducing sugars, proteins, total sugars, moisture, and browning index.

3.1.1 Relationship between the parameters studied during normal drying

The results of parameter behavior for varieties dried without pretreatment (normal drying) are shown in the following figure.

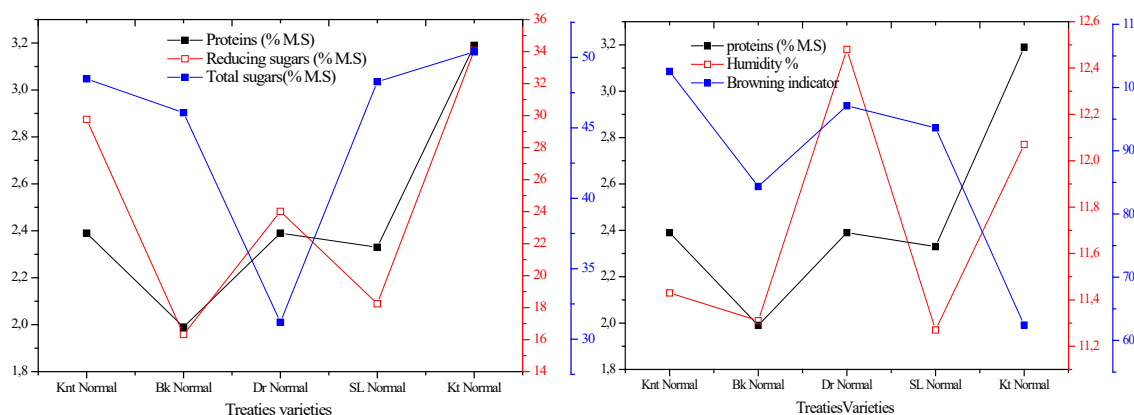


Figure 5. Parameter variation according to drying without pre-treatment.

The results reported in this graph are based on mango varieties dried without pre-treatment (a treatment used by women in Casamance).

The results presented in Figure 5 show similarities between variations in protein and reducing sugars, on the one hand, and protein and moisture, on the other. The results show that some varieties have higher contents than others. However, we note that the quantity of protein and total sugars increases from one variety to another, and that the two curves describe the same trends. Knt and Kt have the highest sugar and protein contents respectively (34%M.S -3.2%M.S and 31%M.S-2.9%M.S). Varieties Bk and Sl show the lowest amounts of sugars and proteins, respectively (17%M.S-2%M.S and 18%M.S-2.3%M.S). Compared with the varieties studied by [8], these varieties show better quantities of total sugars. The opposite is observed with Bk and Sl. No similarities are observed between variation in protein quantity and browning index. However, when the amount of moisture increases or decreases from one variety to another, the amount of protein follows the same progression. Similarities are observed between variations in reducing sugars, proteins, and moisture. This drying shows the moisture content of Dr (12.5%) and Kt

(12.1%) varieties to be within the range (12-18%) given by [9]. The moisture content of all three varieties is below the set average. For a good degree of drying, the products obtained should have a final moisture content of 12-15% [10].

3.1.2 Relationship between the parameters studied during drying with soaking the slices in a sugar solution for two hours

Soaking preserves the fruit's original color. Similarly, the taste is closer to the fresh product (because of the sugar), the shelf life is longer, and the yield is higher [11]. In this figure, we have represented the variation in physicochemical parameters studied during drying with the treatment of the samples in a sugar solution with heating for a duration of two hours.

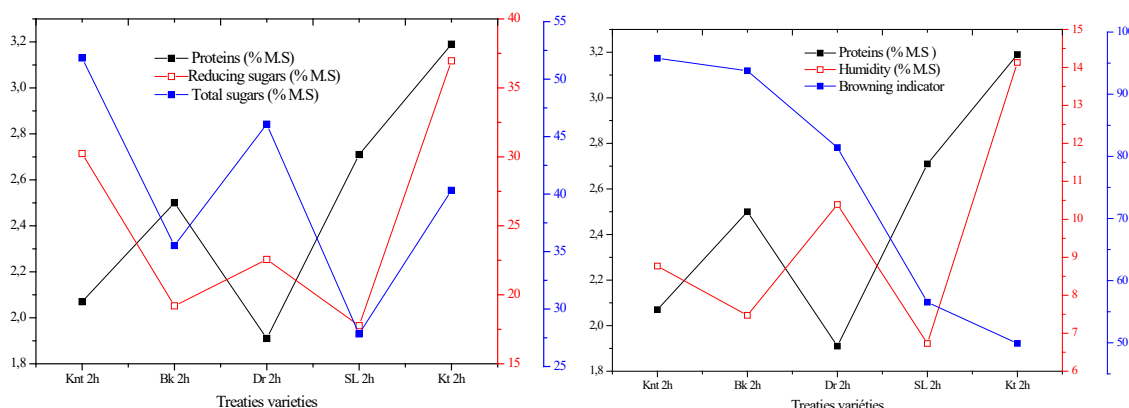


Figure 6. Parameter variation after drying with a two-hour pre-treatment.

The results obtained during this drying process show links between certain parameters. When the amount of total sugars increases or decreases from one variety to the next, the same constant is observed with the amount of total sugars, as opposed to the amount of protein. We also observe that the quantity of total sugars increases or decreases in the same way in the case of normal drying and drying with a two-hour pre-treatment. Protein levels increased slightly in Knt, SL, and Kt. With the exception of Kt, moisture levels dropped considerably everywhere compared to normal drying. The treatment may have an influence on this drop in moisture. For mango, osmotic dehydration offers a loss of water and a conservation of solutes [11]. This drop in humidity can be explained by the fact that part of the water has been eliminated by osmosis during soaking, well before drying.

3.1.3 Relationship between the parameters studied during drying with soaking the slices in a sugar solution for three hours

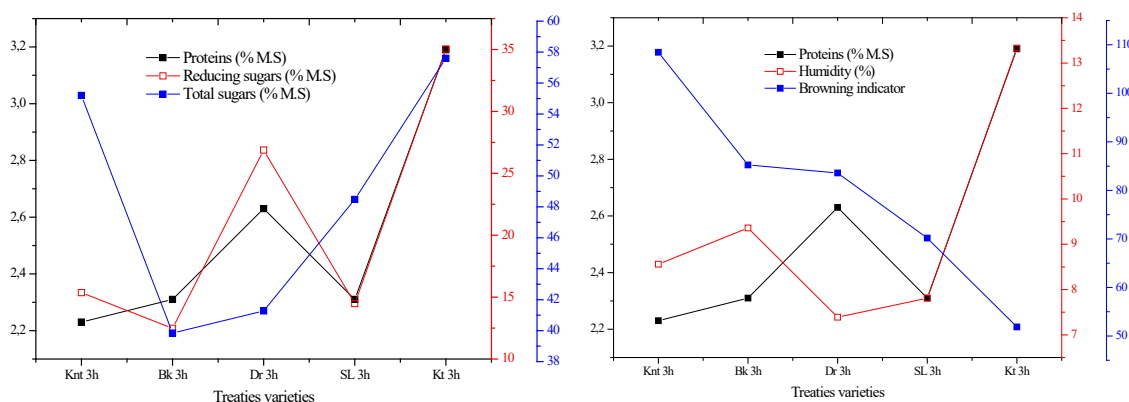


Figure 7. Variation in parameters after drying with pre-treatment for three hours.

The results of this analysis show that there is no relationship between the parameters. However, with the exception of the Bk variety, we observe that the quantities of reducing sugars and proteins increase or decrease in the same way. This time, no relationship is observed between the variation in total sugars and the other parameters. The same is true of humidity. It should also be noted that the browning index varies in the same way in the case of drying

techniques with pre-treatment. According to the three drying techniques used, the Kt variety always has the highest quantities of protein, total sugars, and reducing sugars, and the lowest browning index. Knt has very high levels of total sugars. It seems that the Browning index cannot express the parameters studied. To confirm or refute this hypothesis, we ran a model.

3.1.4 Relationship between browning index and parameters studied

Analysis of variance is used to study the behavior of a quantitative variable to be explained as a function of one or more qualitative variables, also known as categorical nominals [12]. In this figure, we have represented the analysis of variance of the Browning index according to treatment. This analysis of variance is performed to understand the variation of the browning index according to the treatment technique used.

Model construction:

Linear regressions and ANOVA are special cases of the same statistical model, the linear model, which can be written as follows: $Y_{ij} = m_i + e_{ij}$

Where m_i is the fixed, linear part of the model; the expectation of (Y_{ij}) ,

e_{ij} is the random, normal part,

i is the treatment index,

j is the repetition index

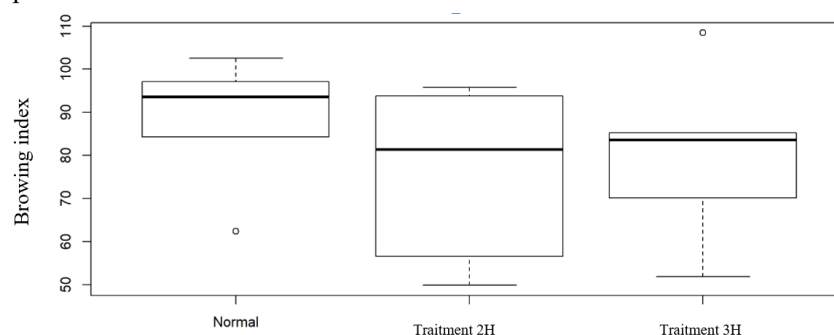


Figure 8. Analysis of variance of browning index.

From the results of this analysis, it appears that the drying technique has little influence on the browning index. The results of this analysis are in line with those obtained according to the links between physicochemical parameters and the processing technique used.

To confirm or refute this hypothesis, we performed a regression of the Browning Index as a function of each variable separately. `lm(Browning_Index ~ Protein, data = df)` dplyr: `select (Browning_Index, Protein, Moisture, Reducing_Sugars, Total_Sugars, Yellowing_Index)`. The results of this regression show that the yellowing index (p-value: 6.224e-10) can inform on the variation of the browning index. This means that, if we know the yellowing index, we can predict the browning index, vice versa. In relation to protein, this analysis shows a link with the browning index. So we can say that the Browning index slightly informs protein variation (p-value: 0.002326). For the remaining variables: total sugars (p-value: 0.766), reducing sugars (p-value: 0.1275), and moisture (p-value: 0.3216) show no relationship with browning index.

The overall results of this model are shown in the figure below.

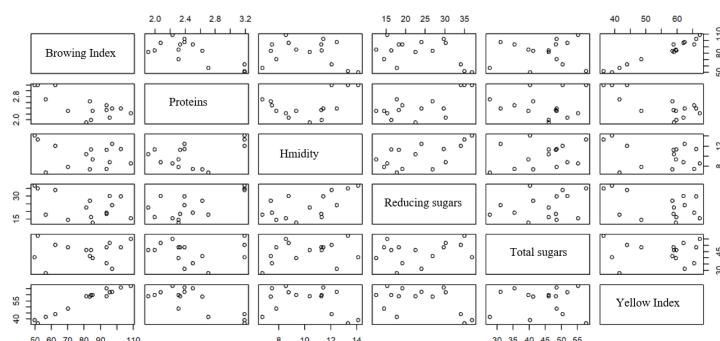


Figure 9. Analysis of variance of browning index.

The results in this figure clearly show the relationship between browning index and yellowing index. As the browning index increases, so does the yellowing index. For a browning index value of 40, the yellowing index value is 50. So, knowing the yellowing index (pvalue:6.224e-10), we can accurately predict the browning index. From the latter, we can predict the other variables, knowing their relationship to each other. Unlike the yellowing index, the results show no link between the browning index and the other variables. This means that these variables cannot be predicted from the Browning index.

4. Conclusion

Drying is a key alternative in the fight against mango losses due to rotting and helps to add value to the product. However, during drying, biochemical compounds undergo many changes under the influence of several factors. The biochemical analyses carried out reveal that nutritional compounds important for healthy eating are well preserved during drying. For reducing sugar and protein composition, the analysis shows that these two variables increase or decrease in the same way in the normal treatment and in the three-hour treatment. And while in the normal treatment, protein and moisture vary in the same way, the opposite is observed in the two-hour and three-hour treatments. Also, this study reveals that knowing one of the two indices (browning or yellowing) can accurately predict the other, but not the other variables. This work proves the performance of the drying technique used by women in Casamance, with good preservation of nutritional compounds on the one hand, and time and cost savings on the other. The results show that local varieties are suitable for drying compared with other varieties found in the literature.

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