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Study of the Impact of Granulometry in the Drying of Rolled Products of Cereal Flour

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Abstract: Such as millet, corn and transformed into "couscous", "arraw" or "thiakri" that fit for human consumption. They are widely used in Senegal where about 70% of the population feed on these products because of their nutritional value and also their availability. Today, only in the small industrial zone of Thies, one can count four producers, who produce each: few tons. But the major problems they face are the drying and packaging of these products after their transformation process. This article is based on the drying of rolled products. It reveals that the granulometry is an extremely important factor in the drying process. The testing on the rolled products showed that the small ball does not dry out faster than larger, as is often thought. This assertion is not always true. This study allowed us to show the different scenarios that may arise as well as their limits. In addition, we determined that the equation of the drying curve of rolled products is generally in the form polynomial of level 4.

Key words: Drying, granulated products, insulating

INTRODUCTION

Product preservation for future consumption poses serious problems. Drying is one technique among many that keeps many products (Ahouannou *et al*., 2000). A good Modeling of drying system passes through the control of several thermophysical phenomena such as convective heat transfer by radiation or conduction (Nand and Kumar, 2010; Jannot and Coulibaly, 1998).

The use of thermal insulation (Ould Brahim *et al*., 2011) also allows efficient use of energies involved for drying. We propose to study the drying of three products made from flour and cereals that are differentiated by the size of seeds formed during the preparation. We name the products différnts "arraw", "thiakhry", "couscous."

MATERIALS AND METHODS

Experimental device:
The experimental device used consists of:

- A series of sieves for particle size analysis of rolled products
- An oven up to a temperature of 100ºC
- A thermometer for measuring the temperature
- Porcelain beakers for contain the product
- An oven to determine the water content of the product
- A desiccator to dehydrate the samples
- An electronic balance with a precision 1/10000.
- The experimental device is shown in Fig. 1.

Procedure: We prepared several samples of rolled products (“couscous”, “arraw”, “thiakri”) mass weight of 500 g (per sample) that have the same water content (Bell and Labuza, 2000). For each sample, we performed a sieve analysis. Then the water content was determined on samples of mass weight of 10 g of each product rolled after oven drying for 24 h at 104ºC.

These samples are then cooled in a desiccator for dehydrate. After determining the water content, the drying tests are performed for all products in a chamber where the ambient air temperature is 28ºC with a relative humidity of 60%.

RESULTS AND DISCUSSION

Particle size analysis of rolled products: The exchange surface provided by the product to be dried is not well defined for these types of products. In the case of granular

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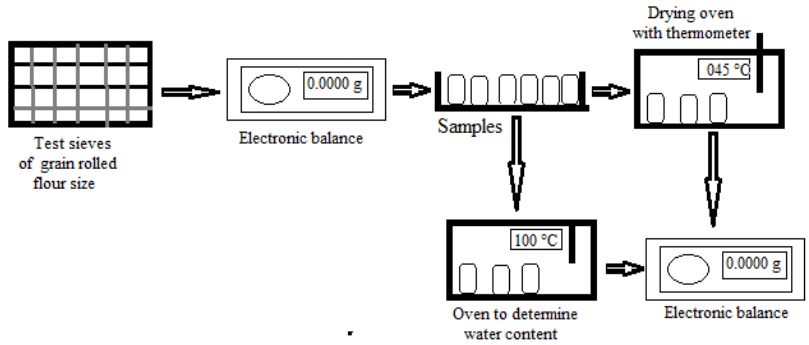

Fig. 1: Schematic of the experimental

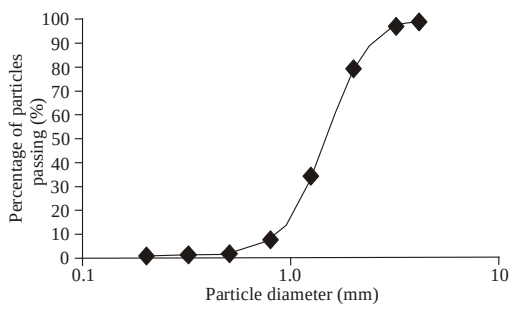

Fig. 2: Granulometric curve of the product "thiakhry"

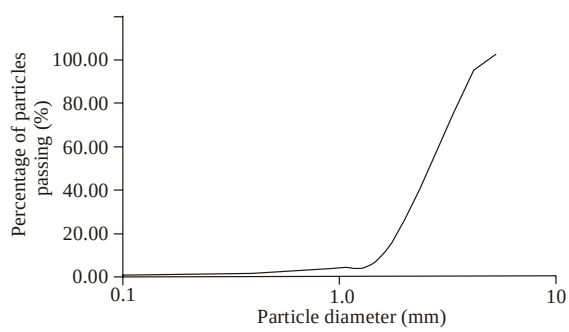

Fig. 3: Granulometric curve of the product «arraw»

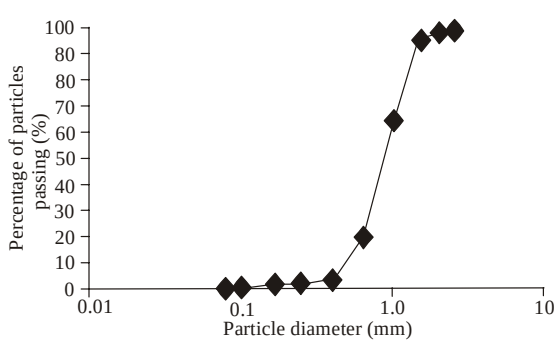

Fig. 4: Granulometric curve of the product “couscous”

solids whose particle size is not homogeneous defining a mean particle diameter. The principle of the calculation is to divide the particle size distribution in slices. In each stage is an average diameter dpi but also a percentage of the total mass Xi on which the particle size analysis was performed. The average diameter of a set of particles is given by the relation (1):

$$dpi(m) = \frac{1}{\sum \frac{X_i}{dpi}} \quad (1)$$

The curves in Fig. 2, 3 and 4 show the evolution of varying sizes:

From the granulometric curves (Fig. 2, 3 and 4), we can calculate the coefficients of uniformity for each product rolled by the relationship (2):

$$Cu = D_{60}/D_{10} \quad (2)$$

D_{60} diameter corresponding to 60% of passers in mm
D_{10} diameter corresponding to 10% of passers in mm
For all three curves, we have $Cu \leq 2$; we can consider the uniform particle size.

The decrease in the size of particles constituting the material to be dried will be an improvement factor of drying. In addition, it will facilitate the diffusion of moisture to the surface of particles. The exchange surface provided by the product to be dried is a determining factor for drying but it is not the only element of assessment for rolled products. This allegation can be generalized, although it acknowledges the limits we tend to obscure. We show limitations of this assertion in following:

Characterization of wet solids: The moisture content of a solid is the mass of water contained in one kilogram of dry solid (Jannot *et al*., 2002). This is the water content of a product on a dry basis expressed by the following formula (3):

$$X_{bs} = m_e/m_s \quad (3)$$

Table 1: Water contents in different samples on wet basis

Products	Couscous	Arraw	Thiakri
Water content in wet base	40%	40%	40%

Table 2: Test product drying granules at 70º

Product	M (g)	MS (g)	MH (g)	TEMPS(h)
Thiakry	10,000	8,467	1,533	1
	10,000	6,037	3,963	5
	10,000	6,027	3,973	5,5
	10,000	6,028	3,972	6
Arraw	10,000	8,042	1,958	1
	10,000	5,986	4,014	5
	10,000	5,939	4,061	5,5
	10,000	5,968	4,032	6
Couscous	10,000	8,270	1,730	1
	10,000	6,019	3,981	5
	10,000	6,018	3,982	5,5
	10,000	6,084	3,916	6

M: Mass of the product; MS: Dry mass of the product; MH: Mass of wet product

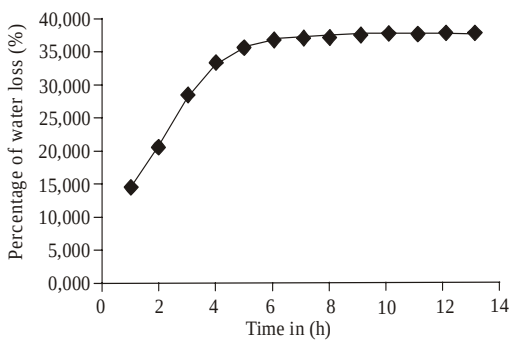

Fig. 5: Diagram of drying "thiakhry": evolution of water loss versus time

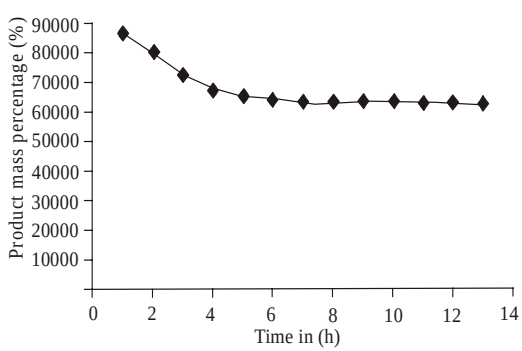

Fig. 6: Curve of drying "thiakhry", evolution of the mass in function of time

The water content of a product is sometimes defined in wet basis (4):

$$X_{bh} = m_e/m \quad (4)$$

The two quantities are related by the following Eq. (5):

$$X_{bs}=X_{bh}/1-X_{bh}\ ; \quad X_{bs}=X_{bs}/1+X_{bs} \quad (5)$$

The drying rate is characterized by the equation:

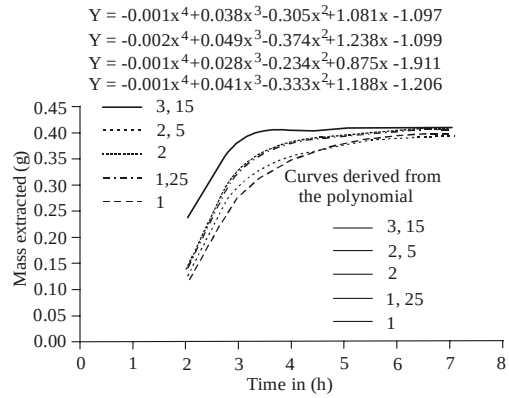

Fig. 7: Drying curves of rolled products: evolution of the mass removed during the drying in function of time for various particle sizes

$$dX/dt=X(t+dt)-X(t)dt$$

Table 1 gives the relative humidity of granulometric products. For the first tests, we followed the recommendations of the producers, setting the maximum temperature at 70ºC. The objective was to determine the ideal temperature for drying. The results are given in Table 2.

By analyzing these results we find that the product rolled “arraw” having a particle size larger dried faster than other products rolled “couscous” and “thiakri” who had a finer particle size. Always at a temperature of 70ºC, free water sprayed too quickly and we found that at the end of drying, the product was altered by changing color. Therefore we changed the temperature of the drying lowering to 50ºC.

For tests at 50ºC, we were interested in the evolution of water loss (dehydration) and mass loss for a period equivalent to the complete drying. Figure 5 and 6 reflect the changes.

The second test at a temperature of 50ºC we found a longer drying time with a better quality product (Talla *et al*., 2004). No color change has occurred and the product has a better texture, with levels of transition between different phases of drying more marked.

Here we have taken the drying tests on samples of a single rolled product (Thiakri) taken from the refusal of the sieve size analysis. This was to confirm the above statement and that challenges what the literature predicted. Figure 7 illustrates the set of drying curves obtained for the same product rolled.

CONCLUSION

The various experiments carried out on rolled products "couscous", "arraw", "Thiakri" showed that the decrease in the size of particles constituting the material to be dried is not always an improvement factor of drying

as some say authors. In the event the product is stacked in multiple layers, we have to take into account the compactness of the product to dry. Under these conditions, problems of loss of higher loads due to the reduction of intergranular porosity will arise.

We have proposed a polynomial function for characterize all drying curves. We have established the ideal temperatures for drying the products used. Nevertheless, the modeling of the drying process of granular products could be further based on analogy with the theory used in flow in porous media.

NOMENCLATURE

"Thiakri": Medium-sized seeds, 2 mm average, obtained from cereal flour.

"Couscous": small seeds, 1 mm on average, obtained from cereal flour.

"Arraw": seeds of considerable size, 3 mm on Average, derived from cereal flour.

dpi: Average diameter of a set of particles

Xi: Percentage of the total mass

m: Mass of product (m = me + ms)

C_u: Uniformity coefficient

m_e: mass of water in the product

D_{60}: diameter corresponding to 60% of passers in mm

m_s: the dry mass

D_{10}: diameter corresponding to 10% of passers in mm

X_{bs}: water content of the product on a dry basis

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