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RESEARCH ARTICLE

COMPARATIVE STUDY ON TWO FOODSTAFF PRODUCTS' PHYSICAL BEHAVIOR DURING THEIR CONVECTIVE DRYING: CASE OF SWEET POTATO AND CASSAVA

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Abstract

During this study, a focus is placed on the physical transformations that cassava undergoes during convective drying.The product continually changes its size, shape, even its texture and consistency. The more moisture a product loses, the smaller its size.Firstly, the results show that water parameters such as mass or moisture content are reduced according to the drying principle.The dimensions length L, width l and thickness e decrease following a linear trend. The mathematical equations describing them were determined using the Excel office tool. This trend impacts surface and volume parameters, which in turn decrease almost linearly with the water content of the product. Note that the R^2 coefficient is not always acceptable, confirming the complexity of the behavior of organic products.

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Introduction:-

In Africa, the production of tubers like cassava and sweet potatoes is crucial. For instance, cassava (Manihot esculenta) has a lot of potential for use as an industrial base. [1]. Even its peel is used to treat mining wastewater, and its derivative products are highly valued [2]. This product must dry in order to be widely used. We want to know if it's possible to combine these two similar products during the drying process. We are aware that the products experience physical changes during convective drying that impact both their dimensions and physical characteristics. [3|-6.

This study compares the physical alterations, specifically shrinkage, that take place when sweet potatoes and cassava are dried convectively.

We will compare these products' physical characteristics and water loss capabilities. Under the same conditions, we will track the development of these products' volumes and surfaces in addition to their linear dimensions [4], [7], and [8]. Several studies have established the linear shrinkage behavior of food materials, including [4]-.6], [8].

Additionally, we will be able to compare the rate of water loss in the products by observing how easily the water

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content varies [4].

Although some heterogeneity is present, the samples were generally considered homogeneous for the purposes of this study.

a) raw cassava

b) Freshly cut samples

c) Samples drying, undergoing deformation

Figure 1:- From raw to drying samples of cassava:
a) raw cassava,
b) freshly cut samples,
c) samples undergoing deformation during their drying process

Materials and methods:-

Obtaining samples and handling

Similarsamples of cassava and sweetpotatoeswerecutfromrecentlypurchasedfoodstuffsfrom the Bobo-Dioulasso local market. Theyweredried by convection in an oven. The temperatureis set to 70°C. The samples are put into the oven to begin the transfer process afterwewait for thermal equilibrium to bereached. The geometric points where the measurements are taken are markedwith permanent ink. To finallytake the averageintoaccount, threemeasurements are taken. Duringperiod of the experiment, samplesweretaken out at preplannedintervals to measure mass and lateral, longitudinal, and thickness dimensions. To avoiddisturbing the product'salready-established thermal equilibrium, wereduce the measurement time.

The geometriccharacterization of the samplesisdone by initiallymeasuring the dimensions as well as the final values. We use for this the digital micrometer (MITUTOYO, Japan, precision 2.10-5m).

Data processing

The material of cassava or sweet potatoundergoes physical deformations while it dries. Cellular collapse brought on by water loss during convective drying causes the product's solid matrix to contract. The models found in the literature are primarily empirical and cannot be applied to different products or drying conditions [9]–12]. However, the literature does contain some fundamental theories [13]. Comparisons are extremely challenging due to the variety and multiplicity of products and their physical characteristics (density, material concentration, contraction coefficient, collapse, porosity, change in dimensions, etc.). [14]-[20]. Type relationships are used to represent contractions based on experimental data:

- case of width and transposable for length and thickness (equation 1):

$$l = a_l X + b_l \qquad (1)$$

- case of the surface and transposable for the volume(equation 2):

$$S = a_S X + b_S \qquad (2)$$

where a and b are constants deduced graphically, the indices S, and l being reported respectively the surface and the width. These models have been used by certain authors for different products and applications: for grapes [21], potato [22], bananas [23], gelatin slabs [24], ocra 25], mango [26], tomato [27].
The difficulty linked to the study of the drying of agri-food products comes from the great diversity in the field. Added to this is the structural factor. The heterogeneity and anisotropicity of the agri-food product give it, during its drying, very complex physical and mechanical characteristics. We can distinguishthree main directions:

- the longitudinal direction (L), which is that of the fibers;
- the tangential direction (T), perpendicular to the plane containing the fibers;

- the radial direction (R), perpendicular to the longitudinal and centripetal axis.

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In the case of agri-foodproducts, the exchange surface S decreasesduring drying and the curves$-\mathrm{dX}/\mathrm{dt} = \mathrm{f}(\mathrm{X})$may not show a first drying phase. The flow $\mathrm{q_m}$is variable. Taking into account the variation of the coefficient m/S, where S varies during drying due to contraction, $\mathrm{q_{m,t}}$can bedefined in the followingform May and Perré, 2002 [28]:

$$\mathrm{q_{m,t}} = -\left(\frac{\mathrm{m}}{\mathrm{S(t)}}\right).\frac{\mathrm{dX}}{\mathrm{dt}} \qquad (3)$$

The main advantage of usingthismethodis to reveal a constant first drying phase in order to facilitate the determination of the critical water content. Indeed, the surface S(t) tends to decrease due to contraction. Thus, according to equation (3), the speed $\mathrm{q_{m,t}}$increases because it is referred to the real exchange surface which decreases.

$\dot{\mathrm{m}}$the mass of water evaporated per unit time given by equation 4:

$$\dot{\mathrm{m}} = \mathrm{m_s}\left(-\frac{\mathrm{dX}}{\mathrm{dt}}\right) \qquad (4)$$

Or

$\mathrm{m_s}$the dry mass of the product[29].

$(-\mathrm{dX}/\mathrm{dt})$the drying speed $(\mathrm{Kg_e}.\mathrm{Kg_{ms}^{-1}}.\mathrm{s}^{-1})$given by:

$$\left(-\frac{\mathrm{dX}}{\mathrm{dt}}\right) = \frac{\mathrm{X(t-\Delta t) - X(t)}}{\Delta \mathrm{t}} \qquad (5)$$

And :

$\mathrm{X(t)}$the water content of the product ($\mathrm{Kg_e}.\mathrm{Kg_{ms}^{-1}}$);

$\Delta\mathrm{t}$the drying time step (s).

Results and Discussions:-

Water contain change during convective drying for sweet potato and cassava

Drying issynonymouswith water loss by the material to bedried. This lossisoftenseen by the decrease in its water content X duringits drying process. For the twoproductssubject to ourstudy, namelysweetpotato and cassava, we follow the evolution of their water content, for parallelepipedsamples of dimensions of approximately 32x20x10cm at a temperature of 70°C. The objective is to compare the relative evolutions of the water contents of theseproducts, all starchy, but withvisiblydifferent structures.

Figure 2 shows the evolution of the water content X for twosamples of sweetpotato (Figure 2a) and twosamples of cassava (Figure 2b) allidentical. They have the parallelepipedshape of the dimensions indicatedabove.

As shown in Figure 2, it can beseenthatcassava loses water more easilythansweetpotato. In fact, in the first 50 minutes, sweetpotatois at 58% of its initial water content, whilecassava's water content isalready at 52% of its initial value.

At one hundred (100) minutes of drying, sweetpotato and cassava have relatifs waters contents of their initial values of 35% and 29% respectively. For 150 min of drying, their water contents drop by 18% and 12% of their initial value respectively. Cassavareachesits asymptote at 230 min of drying and sweetpotatowillonlyreachthis asymptote at approximately 300 min of drying.

Theseresults show that agri-foodproductsbehave in a singularwaywhenfacedwithtransfersduringtheir convective drying. It wouldtherefore not berecommended for a dryer to mix samples of sweetpotato and cassava for drying. Indeed, at the end of drying, either the sweetpotatoisvery dry, whichdegradesitsnutrients and is not appreciated by the consumer, or the cassavais not completely dry, whichdeteriorates the productduringits conservation.

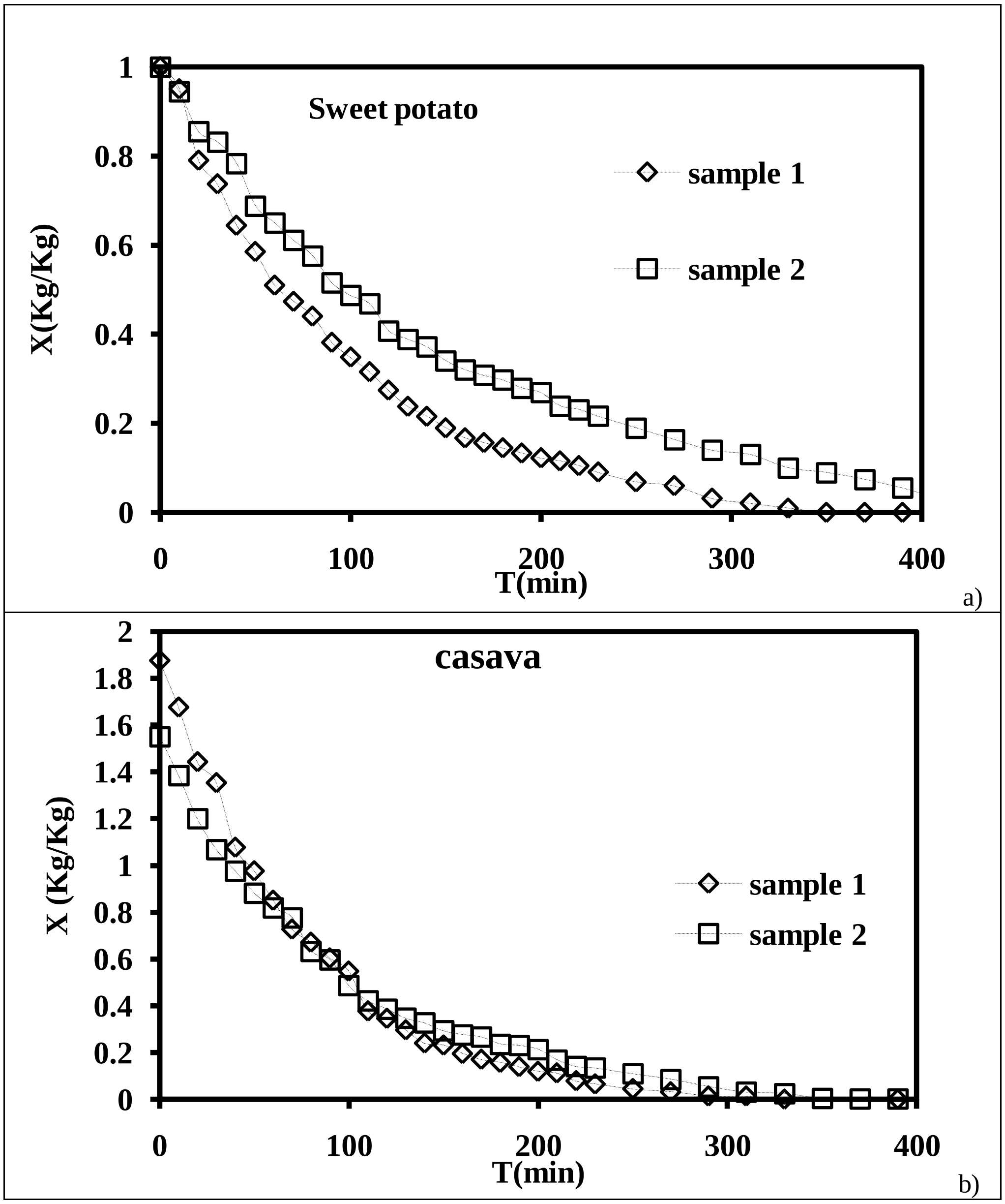


Figure 2:-Evolution of sweet potato(a) and cassava(b) water parameters during their convective drying.

Variation of samples' linear dimension versus water contain

One of the consequences of drying agri-foodproductsisphysicaldeformation, in terms of change in dimensions [30]. This part focuses on changes in linear dimensions such as length, width and thickness of samplessubjected to convective drying. It isalso a question of comparing the behavior of the two (02) starchyproductswhen drying. Figure 3 gives us the evolution of these dimensions during convective drying, both for sweetpotato (figure 3a) and cassava (figure 3b) at 70 ° C. For boththeseproducts, parallelepiped-shapedsamples of length L_0 = 32 cm, width l_0 = 25 cm and thickness e_0 = 10 cm.

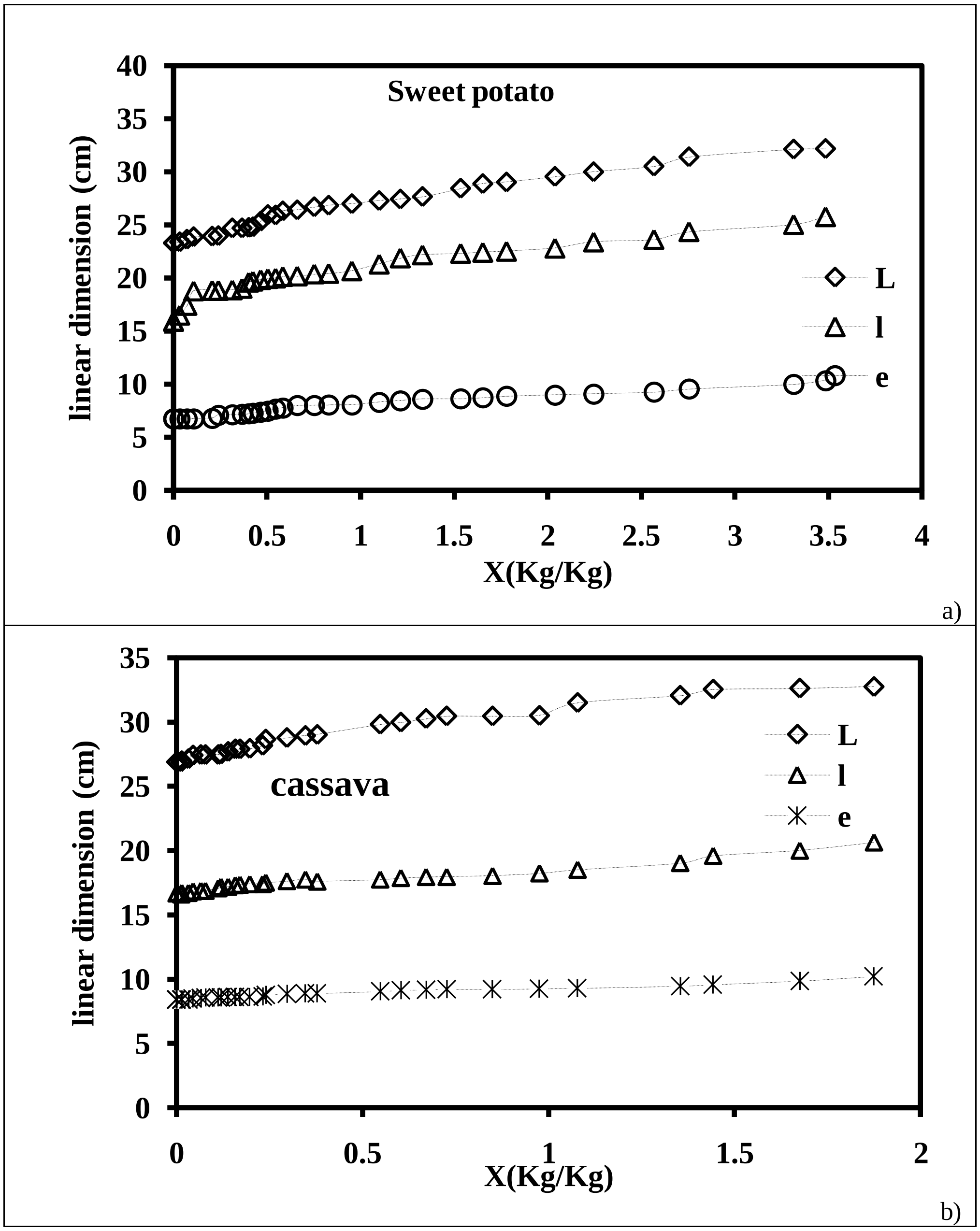


Figure 3:-Changes in linear dimensions of sweet potato (a) and cassava (b) samples during convective drying.

As can beseen, the samplesvarytheir dimensions as they lose water. Theyundergo a decrease in values or contraction.

Considering the case of lengths, we can see in Figure 3 thatits value isonly 30.51 cm after 50 min of drying, 29.81 cm at the 100th minute, 28.17 cm at 150 min to reach 23.28 cm at the end of drying for the sweetpotato.

As for cassava, the lengthis 29.54 cm after 50 min of drying, 27.43 cm at 100 min, 26.41 cm at 150 min and reaches 26.68 cm at the end of drying.

From the length point of view, we can concludethatcassavacontracts more thansweetpotato.

However, if weconsider the width, these values are 22.8cm, 21.86cm, 20.17cm and 15.92cm for sweetpotato, 18.23cm, 17.75cm and 17.42cm and 16.7cm for cassava, respectively at 50min, 100min, 150min and end of drying.

Here, we can clearlyseethatcassavadecreasesitswidth more thansweetpotato, unlike the case of length. This couldbeexplained by the fiber content of cassava. Whencutting, the lengthisperpendicular to the fiberswhile the widthisparallel to the fibers. The structure of cassavabrings the fibersclosertogether and contracts the fibersless.

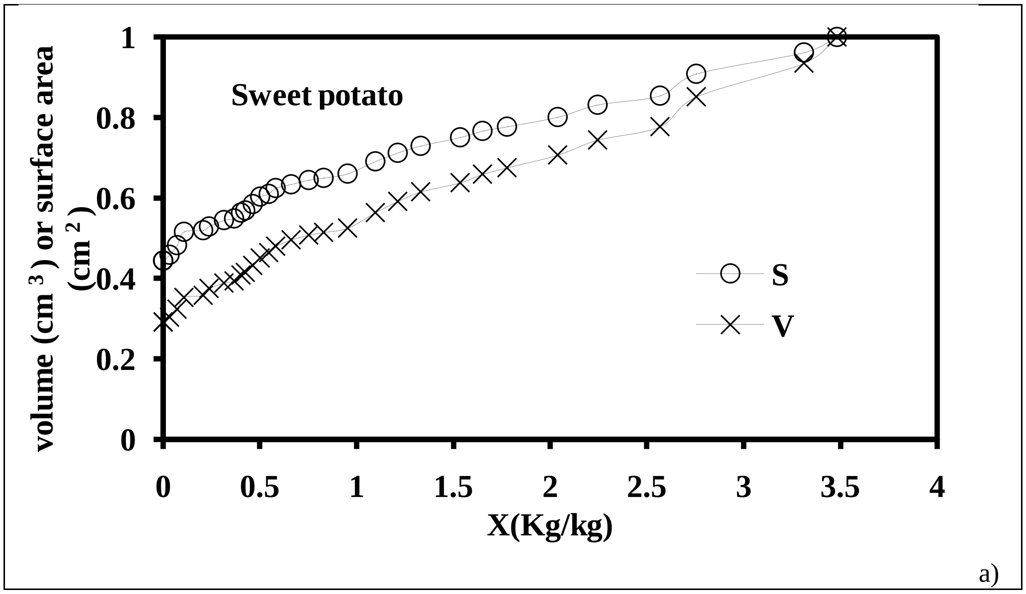
Changes in surface area and volume of sweet potato and cassava samples during convective drying

Some important dimensions whenconsideringtransfers are the volume, whichcontains the water mass to beextracted, and the surface, whichconstitutes the exit door for the moisturecontained in the product. Changingthese dimensions undoubtedly has consequences on the progress of transfersduring convective drying.

Figure 4 contains the curvesshowing the evolution of the volume and surface area of the sweetpotato (Figure 4a) and cassava (Figure 4b) samples at 70°C.

For drying times of 50min, 100min, 150min and the end of drying, the sweetpotato changes fromits initial volume value of V_0 = 8570.07cm^3 to 6048.14 cm^3, 5066.78cm^3, 4250.86cm^3 and 2490.55cm^3. As for the surface area, its initial value changes from S $_0$ = 855.64cm ^{2} to 826.86 cm^2, 718.640 cm ^{2}, 642.99 cm ^{2} and 660.496 cm ^{2}.

Cassava, for thesesame drying times, seesits volume go from V_0 = 6894.79cm^3 to 5144.82 cm^3, 4778.02 cm^3, 4244.74 cm^3 and 3770.72 cm^3. Its surface area goesfrom S_0 = 2441.07cm^2 to 2014.08 cm^2, 1917.18 cm^2, 1770.14 cm ^{2,}1629.93 cm ^{2}.



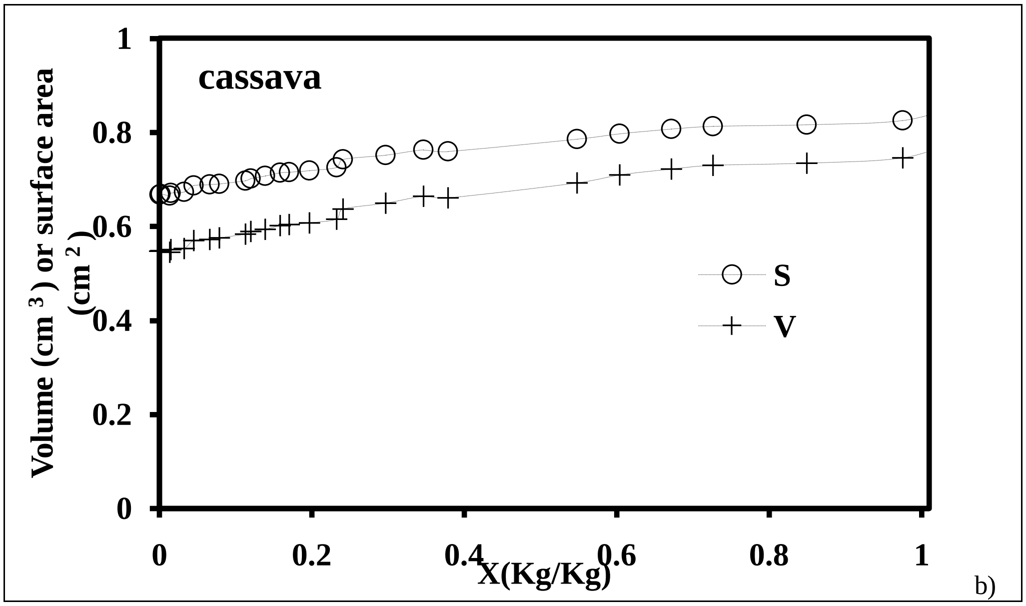


Figure 4:-Evolution of spatial dimensions during sweet potato (a) and cassava (b) drying time.

Variation of sweet potato and cassava density during convective drying

In most cases, customerschoosedriedproductsbased on the firmness of their structure. Theygenerallyrejectproductsthat are too hard in favor of thosethat are more crumbly. Thesephysicalcharacteristics are closelylinked to theirdensity. This densitydepends on the evolution of the dimensions according to the loss of water that the solid matrix to bedriedundergoes. In thisparagraph, the densitythatevolvesduring the drying time iswellfollowed for bothsweetpotato and cassava.

It isclearfrom Figure 5 that agri-foodproductsdecreasetheirdensity by losingtheirinternalmoisture. Note that, in general, cassavadecreasesitsdensity more thansweetpotato. Cassavagoesfrom an initial density of $\boldsymbol{\rho_0}$ =1044.49 g/cm^3 to a final density of $\boldsymbol{\rho_S}$ =664.38 g/cm^3. As for sweetpotato, itgoesfrom an initial density of $\boldsymbol{\rho_0}$ =860.86 g/cm^3 to a final density of $\boldsymbol{\rho_S}$ =660.49 g/cm^3. Bothproducts have approximately the same final density. It isalsonotedthat the decreaseis quasi-linear, with values very far from the linear trend. Indeed, during drying, the product cracks in places, leading to a strongevacuation of moisture, thusconsiderablychanging the density.

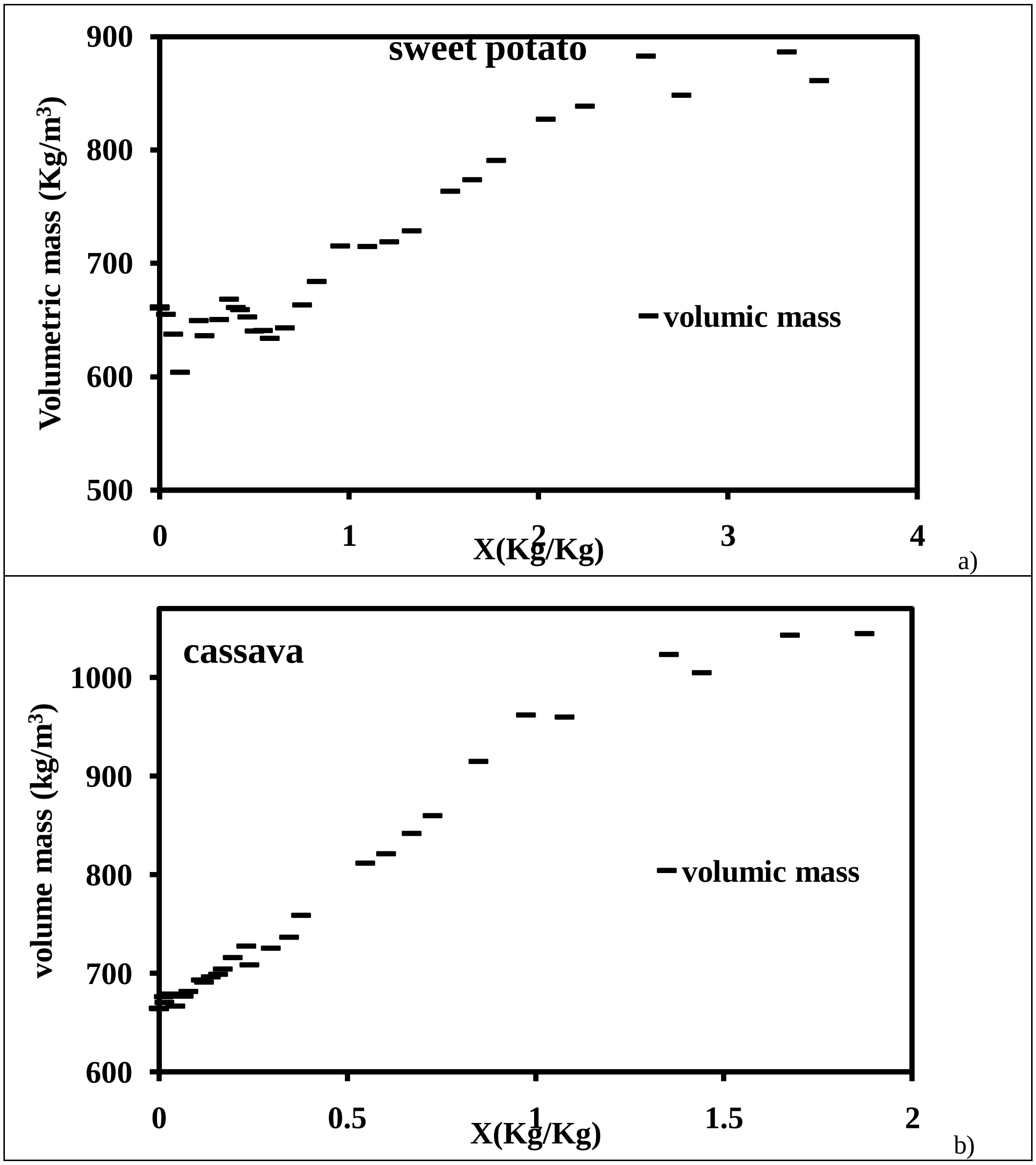


Figure 5:-Variation in the density of sweet potato (a) and cassava (b) samples during convective drying.

Comparative study of sweet potato and cassava drying velocity

Since drying an agri-foodproductinvolves a loss of water, itsefficiencyisrelated to the speed withwhich the water leaves the product. Usingequation 5, we have established the drying speed curves for bothsweetpotato and cassava, contained in Figure 6

We can observe an overallshapethatis consistent with the literature[4 ; 7] .However, the first phase related to the loss of free water is not observable for thesesamples. This maybe due to theirsmall size or the cutting time, which if long, allows the free water to evacuatebefore the effective start of drying. The phases of irregularity of the speed are more remarkable for cassavathan for sweetpotato. In fact, cassava cracks more regularlyduringits convective drying more than the potato. However, cracking releases more water.

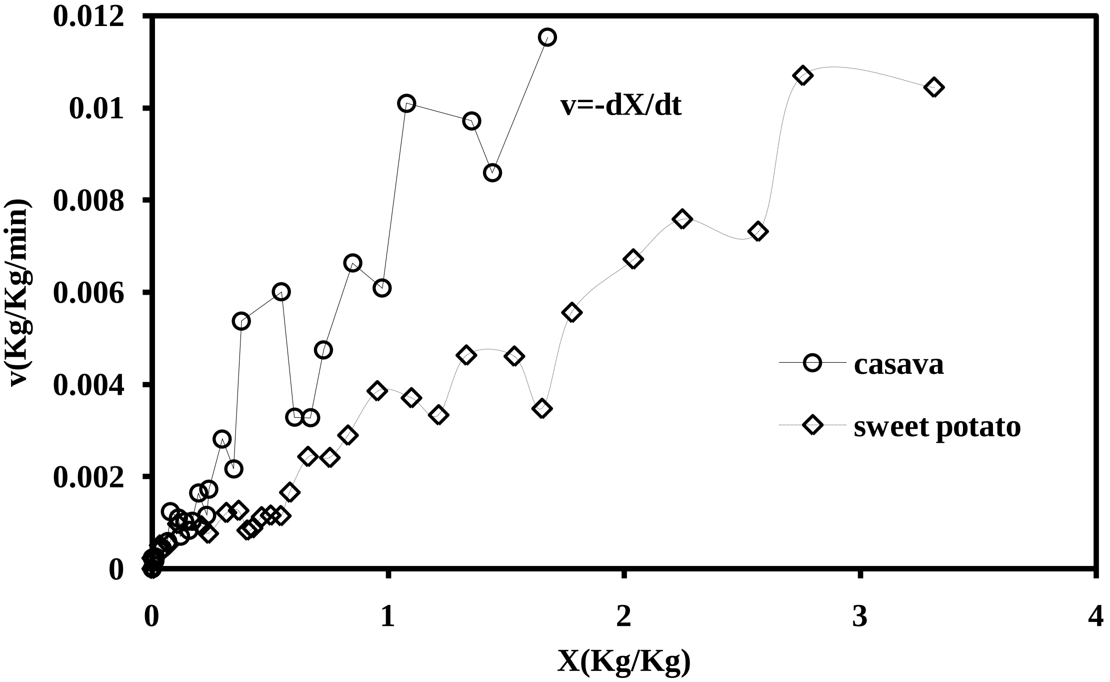


Figure 6:-Comparison of drying velocity of sweet potato and cassava during drying process.

Conclusion:-

Examination of the water content X evolutioncurvesduring convective drying indicatesthatcassava loses water more easilythansweetpotato. In 50 minutes of drying, sweetpotatoreaches 58% of its initial water content, compared to 52% for cassava. Fromthisresult, itwouldtherefore not berecommended for a dryer to mix samples of sweetpotato and cassava for drying. This mixture wouldgivefinishedproductsthat are not uniformlydried, leading to conservation problems.

Consideringphysicaldeformations, cassavafavors the direction perpendicular to the fiberswhichcontracts more thanthatparallel to the fibers. For sweetpotato, this observation is not markedenough, certainlylinked to the lowfiber content compared to cassava.

The physical change isvisibly observable in the surface and volume values, which in turn influence the evaluation of the outgoing mass flow as well as the density of the product.

This density, seen in terms of volumetric mass, gives a decrease for bothproducts. In general, cassavadecreasesitsdensity more, compared to sweetpotato. Cassavagoesfrom an initial volumetric mass of ρ_0 =1044.49 g/cm3 to a final volumetric mass of ρ_S =664.38 g/cm3. As for sweet potato, it goes from an initial volumetric mass of ρ_0 =860.86g/cm3 ^{to} a final volumetric mass of ρ_S =660.49g/ ^{cm3}

The rate of water loss of the product shows more remarkable phases of irregularity for cassavathan for sweetpotato. This isexplained by the factthatcassava cracks more regularlyduringits convective drying thansweetpotato.

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