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Research Application Summary

Investigation into the drying behaviour of Cocoyam (*Colocasia esculenta* (L.) Schott)

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Abstract

This study provides an insight into the drying behaviour and the significance of controlling process settings during cocoyam drying to balance the needs of the food processor and the final consumer. The drying temperature and slice thickness influenced the drying rate, drying time, total colour change, rehydration ratio and specific energy consumption. This study is part of a larger extensive study on value addition to nutritious traditional African crops to reduce post-harvest losses, to boost food security and to enable household nutritional diversity.

Keywords: Cocoyam, convective drying, colour change, rehydration ratio, energy consumption, food security

Résumé

Cette étude donne un aperçu sur le contour du séchage du taro et de l'importance du contrôle des paramètres du processus de séchage du taro afin de trouver un équilibre entre les besoins du transformateur alimentaire et ceux du consommateur final. L'étude a démontré que la température de séchage et l'épaisseur des tranches de taro ont influencé le niveau de séchage, le temps de séchage, le changement de couleur, le ratio de réhydratation et la consommation d'énergie. Cette étude fait partie d'une recherche plus vaste visant à augmenter la valeur des cultures traditionnelles africaines nutritives afin de réduire les pertes post-récolte, de renforcer la sécurité alimentaire et de permettre la diversité nutritionnelle au sein des ménages.

Mots clés : Taro, séchage convectif, changement de couleur, ratio de réhydratation, consommation d'énergie, sécurité alimentaire.

Introduction

Root and tuber crops, including Cocoyam, are the second most important food crops for direct human consumption in Africa, after cereals (Saipriya *et al*., 2017). Despite the strategic importance of Cocoyam as a potential food crop to combat food insecurity and malnutrition in Africa, it remains a neglected crop with limited investments towards research and development. Cocoyam is widely grown in West African countries such as Nigeria and Cameroon (Grimaldi and van Andel, 2018), while in East Africa, it is a low-cost subsistence crop farmed primarily by small-scale farmers

(Munguti *et al*., 2012). Cocoyam has been shown to yield high quality starch per acre of land (Pereira *et al*., 2015), various micro-nutrients (Alcantara *et al*., 2013) and medicinal value (Grimaldi and van Andel, 2018). These aspects make cocoyam a nutritionally superior crop as compared to cereals. As such, it can be used as a raw material to manufacture functional foods for special needs such as baby formula and people with chronic medical conditions.

A study by Muthayya *et al*. (2013) on the global incidence of hidden hunger found that sub-Saharan Africa has a severe to alarmingly high incidence of hidden hunger. Hidden hunger presents itself in the form of deficiency of vital micronutrients either as a result inadequate food intake or intake of sufficient food but poor in micronutrients. The severity of hidden hunger is becoming more entrenched in modern African societies especially in the face of increasing rural to urban migration and abandonment of agriculture by the youthful generation. Evidence from Tanzania suggests that migrants to urban areas neglect the consumption of traditional staple foods in favour of convenient and easy to access foods which are often unhealthy (Cockx *et al*., 2019). Current methods of food processing must evolve to be more sensitive to the needs of this particular consumer. Cocoyam, being a nutrient dense crop, can be carefully dried for direct consumption or fortification of food stuffs derived from readily available staple crops.

Some information on agronomy, production and post-harvest handling of cocoyam is available in literature. However, direct linkages between information available in literature to the specific requirements of food processors and consumers are not fully explored. These linkages are key to the success of the cocoyam value chains in sub-Saharan Africa. The results provided in this study form a part of a bigger study on process control of convective drying with the final consumer in mind. The bigger study is working to generate data and information for the design and optimization of preservation and storage systems for small-scale farmers and mid-level food processors involved in the cocoyam value chains. Ultimately, the study aims to contribute to the reduction of post-harvest losses, improvement of household food security and nutritional diversity and generation of additional incomes to farmers and agro-enterprises through value addition.

Study description. This study utilised *Colocasia esculenta* (L) Schott cultivars grown and harvested at the recommended level of maturity (between 6 — 8 months) for laboratory experiments. During harvesting activities, a visual inspection was conducted to select rhizomes without injuries and defects.

Drying experiments were conducted to study the effect of temperature and slice thickness on the final physical attributes of cocoyam specifically drying rate, total drying time, colour change, rehydration ratio and specific energy consumption after convective drying. Experiments were conducted at fi xed air velocity, fixed relative humidity, three levels of temperature (40°C, 60°C and 75°C) and three levels of slice thickness (4mm, 7mm and 10mm) in a HT-Mini Hohenheim drier (1nnotech-Ingenieursgesellschaft GmbH, Germany. Moisture content was determined using the gravimetric method using a Sartorius Excellence E2000D weighing balance (Sartorius AG, Germany). Colour change was determined using Konica Minolta CR400 colourimeter (Minolta, Japan) and profiled using the CIELab colour space. Rehydration ratio was calculated using the method proposed by Lewicki (1998). Four points were selected along each drying run where samples were drawn out for rehydration. Slices were placed in boiling distilled water for five minutes and the ratio of the rehydrated weight to the fresh weight calculated.

The specific energy consumption (Es) was estimated using the method proposed by Koyuncu *et al*. (2007) and Aghbashlo *et al*. (2008). The Es was determined as a function of the cross-sectional area of the drying tray holding the slices, air velocity, density of air, specific heat of air, temperature difference, total time of each drying run and initial weight of the slices. Experimental drying data were fitted to the Peleg model and Weibull distribution and the Exponential distribution. Model parameters were established using non-linear regression in MATLAB (Mathworks Inc., USA). The quality of fit of predicted data to the experimental data was assessed using the coefficient of determination (R2), adjusted coefficient of determination (R2.adj) and the lowest Root Mean Square of Error (RMSE) and Sum of the Squared Errors (SSE). The model with the highest R2 and R’.adj and the lowest RMSE and SEE was selected.

Research application

Preliminary results from this study reveal that the Peleg model best fited the experimental drying data. Figure (1) and Figure (2) show the drying kinetics at the selected levels of temperature and slice thickness. Drying kinetics provide a basis for the design and optimisation of industrial dryers (Ratti, 2001). Moisture removal from the cocoyam material exhibited a decreasing exponential behaviour from the start to the end. The drying time decreased when the temperature was increased from 40°C to 75°C. Figure (2) provides a sample of the results at a drying temperature of 40°C. As expected, an increase in the slice thickness resulted into a corresponding increase in the drying time to dry to a final moisture content of 10 per cent on a wet basis.

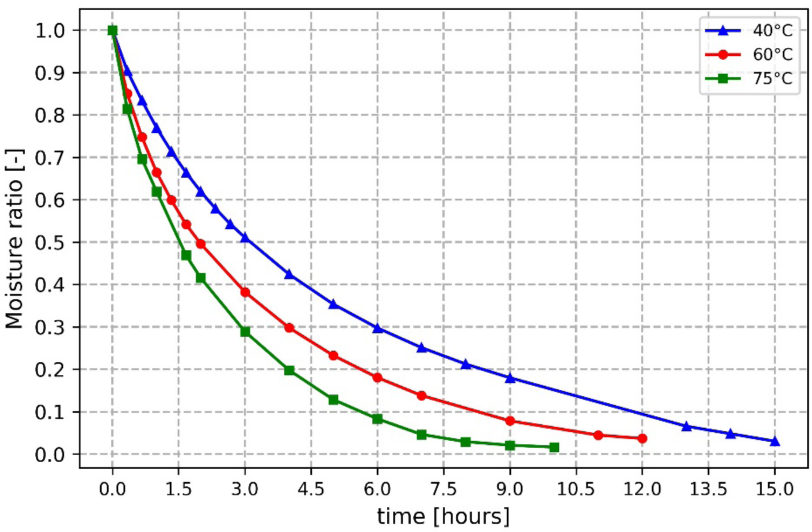

Figure 1. Drying kinetics showing the effect of drying temperature on the drying time

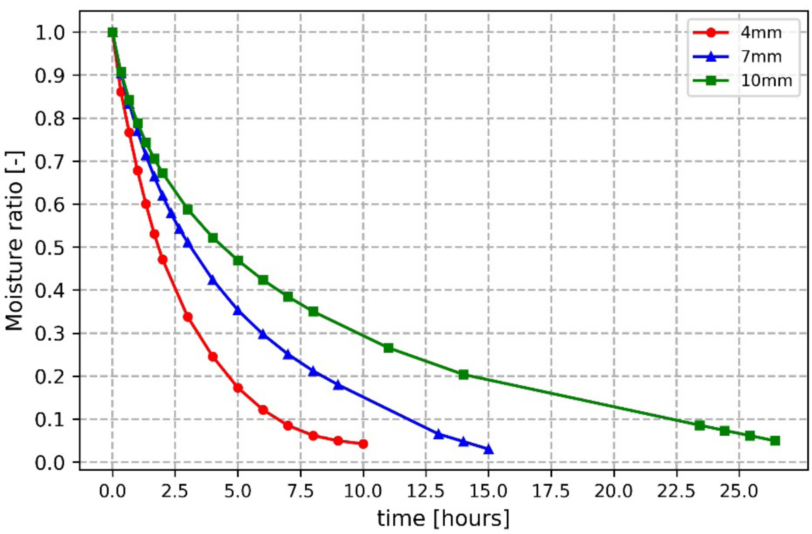

Figure 2. I ng time

A process manager interested in increasing the throughput of their plant could do so by implementing mechanisms to reduce the processing time and increase the drying rate. This can be achieved by increasing the process temperature and reducing the slice thickness (Limpaiboon, 2011; Sairam *et al*., 2017). However, earlier studies have shown that increasing the process temperature destroys important food pigments, nutrients and structure (Sturm *et al*., 2014). Figure (3) provides preliminary results on the kinetics of the total colour change (ΔE) as a function of change in lightness, redness and yellowness of the slices at a drying temperature of 40°C. It was observed that ΔE increased rapidly during the initial stage of drying than towards the end of the process because almost all the pigments are destroyed during the initial stage of drying. Further, the cumulative effect of browning reactions increased during each drying process contributing to the total colour change.

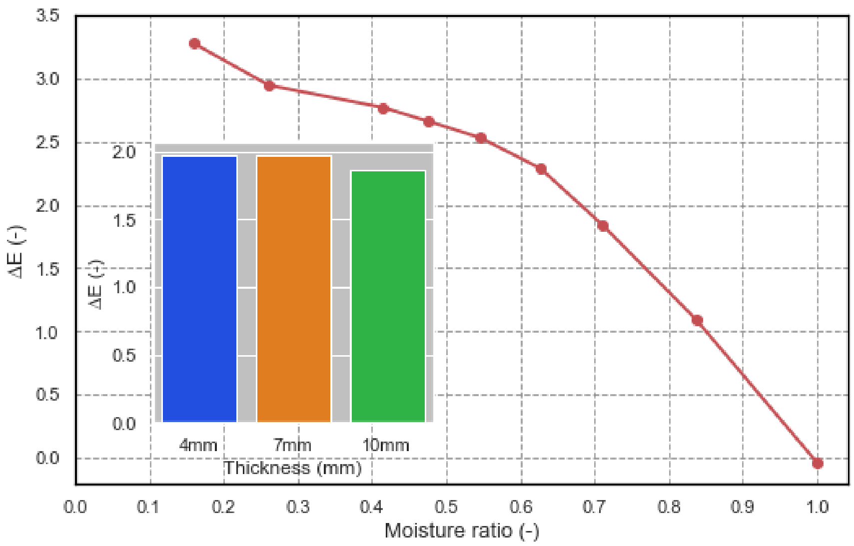

Figure 3. Evolution of total colour change (SE) against moisture ratio

Figure (4) provides a plot of the rehydration ratio against the moisture ratio at the selected sampling points. The plot shows the effect of slice thickness on the rehydration ratio. The rehydration ratio was found to decrease with an increase in the slice thickness from 4mm to 10mm and with the progress of moisture removal from the slices. According to Ratti (2001), food materials possessing a lower rehydration ratio can be considered as poor quality. A decreased ability to rehydrate indicates higher incidence of structural damage (Miraei *et al*., 2018). In Figure (4), at moisture ratio between 0.0 to 0.3, the rehydration ratio is at its lowest indicating maximum structural damage to the cocoyam material at that range.

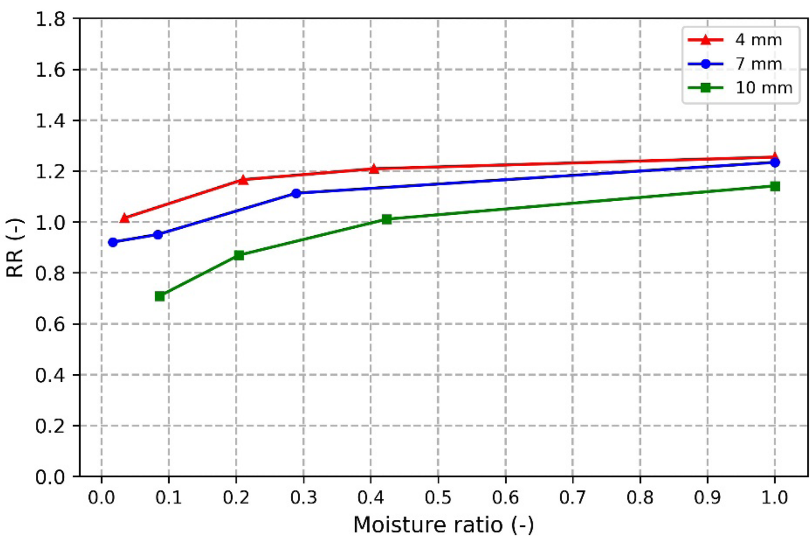

Figure 4. Evolution of rehydration ratio showing effect of slice thickness

The return on investment is a key consideration while establishing a new business, and a food processing business is not an exception. Key business decisions must be made to optimise food drying so as to cut costs. Reducing energy consumption during drying can contribute to reduced processing costs. An estimated 15 to 20 per cent of industrial energy is consumed during drying (Kemp, 2012). This signifies the importance of carefully selecting process settings for optimal plant performance. As demonstrated in Figure (5), energy consumption estimates during cocoyam drying were influenced both by the drying temperature and slice thickness. Energy required to dry 4mm slices was the lowest while 10mm slices required the highest amount of energy. This makes sense since the 10mm slices held more moisture than the 4mm slices hence more energy was need to dry them.

Conclusions and recommendations

This study demonstrated the drying behaviour of cocoyam at the various drying temperature and slice thickness settings. In particular, the dynamic change of moisture content and total colour has been demonstrated. Indicative results on the rehydration ratio and specific energy consumption have also been obtained. Numerous studies have explored the drying characteristics of traditional African food without careful consideration of the needs of the consumer. This study provides an insight into the significance of controlling process settings during cocoyam drying to balance the needs of the food processor and the final consumer. These results are a part of an extensive study on process control of convective drying with the final product quality in mind. Further studies will focus on optimising the process temperature, air velocity and relative humidity to achieve better outcomes of the colour retention, nutrient retention, rehydration ratio, texture and other organoleptic properties. Quality will be analysed through hyper-spectral and multi-spectral imaging, colourimetry, microscopy and textural studies.

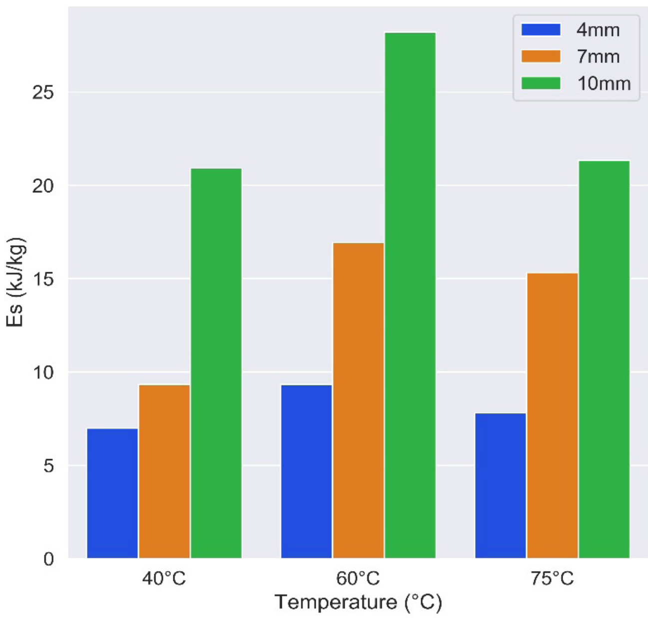

Fig 5. specific energy consumption

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