

Textural and Rheological Characteristics of Sun-dried Banana Traditionally Prepared in the North–East of Thailand

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Received November 7, 2009; Accepted March 10, 2010

Traditionally prepared sun-dried bananas were evaluated for textural and rheological properties. Assessment of how those properties changed over a storage period of two months was also carried out. The texture analysis results that relate to large deformations of the product show that the samples were not significantly affected by storage for one month, but subsequent storage for an extra month did result in softer samples. Rheological characterisation shows that upon heating samples become more elastic, however, this behaviour was reversed upon cooling. The rheological behaviour did not change significantly over the two month storage period. Overall results indicate that textural changes are not the limiting factor in the shelf life of this product. Further work is recommended in order to improve our understanding and maximise the stability of the product over the anticipated shelf life.

Keywords: sun-dried banana, texture, rheology, storage stability, preservation

Introduction

Banana is one of the major commercial fruits grown extensively in tropical and subtropical countries (Chauhan *et al.*, 2006). Bananas are typical climacteric fruit and it is well established that their properties change during ripening (Wills *et al.*, 2007). Ripe banana is very perishable and subject to fast deterioration after harvesting (Demirel and Turhan 2003), being particularly susceptible to excessive softening, discolouration and microbial decay (Chauhan *et al.*, 2006). Considerable amounts of this fruit are wasted due to the lack of efficient preservation techniques (Maskan 2000) and various methods have been employed in order to reduce those losses.

Drying makes it possible not only to stabilise the product by reducing its moisture content or water activity, but also to create new ranges of products (Boudhrioua *et al.*, 2002). A number of drying methods have been employed and studied, such as air drying (Chua *et al.*, 2001; Nguyen and Price 2007; Prachayawarakorn *et al.*, 2008; Leite *et al.*, 2007), microwave drying (Maskan 2000), osmotic dehydration

(Krokida *et al.*, 2000a; b), and solar drying (Phoungchandang and Woods 2000); those studies have focused on modelling the drying process, or determining the effects of various parameters on the final product.

In Thailand, sun-dried banana is popular as a snack food and useful as a preserved product (Phoungchandang and Woods 2000). The volume of bananas produced in South East Asian countries and Thailand in particular makes them an important source of income for a number of small scale producers (Wills *et al.*, 2007). Any processing, such as drying, that can add value and diversify the market is, therefore, of great importance. Sun-dried bananas are in effect minimally processed products and their quality attributes such as colour, aroma, and texture will be changing not only during processing (Boudhrioua *et al.*, 2002; 2003) but also during storage (Chauhan *et al.*, 2006; Golding *et al.*, 1999).

There have been no research studies dealing with the properties of the finished product, especially during extended storage periods. In this study an attempt is made to determine the textural and rheological properties of sun-dried bananas and evaluate how those properties change during storage. It is envisaged that establishing those properties will allow for optimisation of the empirical low-tech production process

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thus benefiting producers.

Materials and Methods

Materials Sun-dried banana samples were prepared in Loei, North East Thailand. The samples were manufactured as follows (mimicking the production of local commercially available samples): locally produced, fully-ripen (based on the colouring chart of Wills *et al.* (2007)) bananas (*Musa sapientum* L.) were sun dried for 48 h (to an approximate diameter of 1.5 cm), and subsequently were pressed to a thickness of 1.5 mm. Pressure was applied mechanically in two stages, firstly a roller was used to flatten the samples before passing them through a home made system of two counter-rotating cylinders (similar to pasta or noodle making) with controlled distance between them. The product was then sealed into polyethylene bags (15×15 cm). Thirty replicate samples were produced. Commercially, the shelf-life of the product is not expected to exceed 6 weeks.

Proximate analysis Proximate analysis was performed (in duplicate) according to AOAC (2000).

Oscillatory rheology measurements The rheometer used was a TA ARG2 (TA, Crawley, Sussex, UK), with a plate-plate geometry. The diameter of the stainless steel probe was 60 mm. Samples were kept at 5°C until tested. The samples were conditioned at 20°C for 5 minutes and then heated to 75°C at a rate of 3°C/min, before being cooled to 20°C at the same rate. The frequency used was 1 Hz, the strain was 0.2% and the gap used was 1.5 mm. Tests were performed in triplicate.

Texture analysis The instrument used was a Texture Analyser TA-HDi (Stable Micro Systems, Godalming, Surrey, UK) using a 49.03 N load cell. The data analysis was performed using Texture Expert Exceed software (version 2.64). Two different tests were carried out, a penetration test, and a slicing test. Both tests were carried out at 25°C. For the penetration test the trigger force was 49.03 mN. The samples (discs 6 cm diameter) were placed and secured onto the platform; a cylindrical probe (diameter: 5 mm, test speed: 2 mm/s, pre- and post- test speed: 10 mm/s) was then forced through the sample (total distance 20 mm). Samples were positioned so that the rod penetrated their geometric centre. The force and the work required to achieve the puncturing of the sample were recorded. Tests were carried out in 5 replicates. Slicing tests were performed using a Warner- Bratzler blade, through a rectangular-hole bearing platform. The test-speed of the blade was 1 mm/s (pre- and post-test speed was 10 mm/s) and the total distance travelled was 30 mm, to ensure complete slicing through the sample. The trigger force was 196 mN. Samples (strips 10 cm × 2 cm) were positioned so that the blade cut them in half, and were tested in triplicate

and the force and work required for the slicing were recorded.

Statistical Analysis Analysis of variance (ANOVA) was carried out using SigmaStat (version 3.0; Jandel Scientific, Corte Madera, CA, USA). Tukeys multiple-comparison test was used to determine differences between treatment means. Treatment means were considered significantly different at $P \leq 0.05$.

Results and Discussion

Proximate analysis Proximate analysis was performed in duplicate and the samples were found to contain an average of 9.18% water, 2.70% protein, 0.64% fat, 2.67% ash, 75.58% carbohydrates and 9.23% crude fibre. The pH of the samples was 4.6.

Rheological properties The rheological stability of sun-dried bananas was evaluated by heating and subsequently cooling at rates resembling cooking. The results (Figure 1) indicate that the initial drying of the products facilitates the preservation of the structural integrity of the product during those temperature fluctuations. Previous research has only dealt with the effect of the drying process (Chauhan *et al.*, 2006; Krokida *et al.*, 2000b; Nijhuis *et al.*, 1998) and not with the effect of heat on the dried product, rendering a comparison unsound. The current evaluation is necessary since the product is very likely to be used as an ingredient. The elastic moduli of the samples were significantly ($P \leq 0.05$) reduced during heating, which was not unexpected given the low moisture and high carbohydrate content. Although the heating and cooling applied was rapid (3°C/min), the heat applied appears to have been enough to denature some of the proteins present in the products. Such denaturation, together with gelatinisation of starch would explain the relatively lower values of G' on the same temperatures during cooling.

This observation is in accordance with previous work where protein denaturation (and therefore weakening of the structure of the product) in bananas treated at temperatures of about 70°C has been reported (Leite *et al.*, 2007). However, the overall effect on the samples, as expressed by changes in $\tan \delta$ (which is the ratio of G''/G' (viscous/elastic moduli)) was a softening one, albeit not significant ($P \leq 0.05$) until the samples were cooled below 30°C.

The results indicate that the samples were stable in terms of their rheological profile over storage periods comparable to their expected shelf-life (Figure 2). No significant differences were observed for G' or $\tan \delta$ during heating. That would indicate that rheological changes are not expected to be the limiting factor when determining the products shelf-life. Changes of the organoleptic properties, such as off-flavours and odours due to fermentation are more likely to

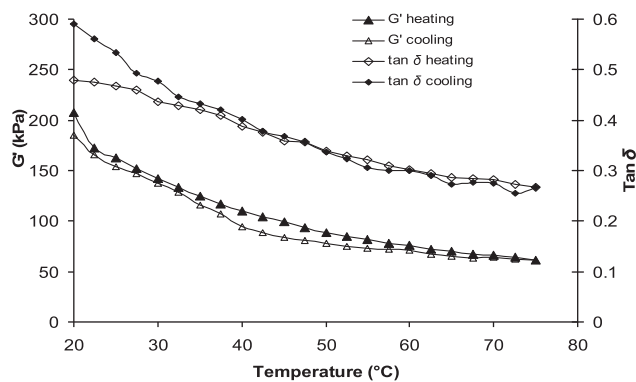


Fig. 1. Effect of temperature on the elastic modulus (G') and loss tangent ($\tan \delta$) of sun-dried bananas.

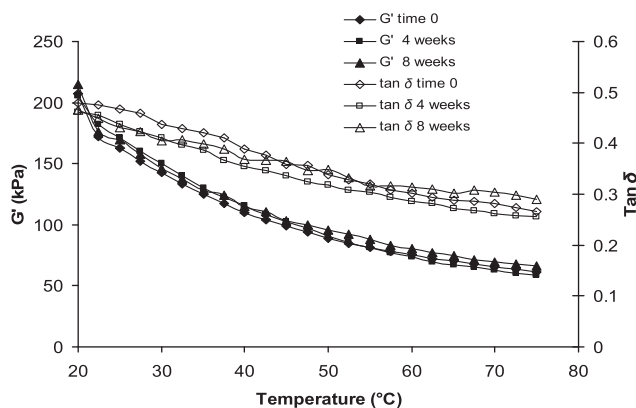


Fig. 2. Effect of storage time on the temperature profile on the elastic modulus (G') and loss tangent ($\tan \delta$) of sun-dried bananas.

limit the life of this product.

Texture

a) Piercing properties Large deformation of the samples, as determined by the force and work required to pierce and slice them, was also carried out. The results for piercing are summarised in Table 1. The results indicate that storing the samples for 4 weeks had no detrimental effect ($P \leq 0.05$) on the texture of the samples. Further storage did result in samples that were easier to pierce although the changes were not significant ($P \leq 0.05$) however the samples yielding those results were already starting to develop off-flavours due to the fermentation, thus making the product undesirable. Earlier studies (Prachayawarakorn *et al.*, 2008) have indicated the importance of the drying temperature and rate of drying on the texture of dried banana slices. However, the temperature range during that study (Prachayawarakorn *et al.*, 2008) was higher than the one anticipated during sun-drying, resulting in slices with approximately half the moisture content, therefore resulting in a much firmer product.

b) Slicing properties Similar results were obtained for samples that were sliced rather than pierced. The results are summarised in Table 2. The only significant ($P \leq 0.05$) differ-

ence observed was for the work required to slice the samples after 8 weeks of storage. Again, however, those would be non-decisive changes since the off-flavours development would have rendered the product unsuitable for consumption. Lack of comparable studies would highlight the need for further testing; using more controlled drying conditions as well as a range of storage conditions, in order to confirm and expand on our findings.

Conclusion

Sun-drying of bananas is the cheapest method of producing a value added product that is of great importance to small scale producers in developing countries, as it allows for extended shelf life and ease of transport and distribution. The evaluation of sun-dried bananas traditionally produced in the North-East of Thailand revealed that the product is rheologically and texturally stable for periods of time similar to the expected storage time. Differences observed were largely not significant and only storage for extended periods of time had a noticeable softening effect. It can, therefore, be concluded that the limiting factor on the shelf-life of those products would be the fermentation inside the pack rather than textural and rheological changes. It is recommended that further tests are carried out using i) a range of drying periods, ii) different storage temperatures and iii) different packaging materials, in order to obtain a more complete understanding of the textural and rheological changes and extend the shelf life of this added-value product in order to maximise the potential benefit to small scale producers especially in developing countries.

Table 1. Effect of storage time on the force and work required for piercing sun-dried bananas.

Storage time	Force (N)	SD (n=5)	Work (N*mm)	SD (n=5)
1 week	13.38 ^a	2.26	24.21 ^a	3.47
4 weeks	13.60 ^a	2.07	24.31 ^a	3.64
8 weeks	11.87 ^a	2.15	22.52 ^a	3.22

For each column, means with the same letter do not differ significantly at $P \leq 0.05$.

Table 2. Effect of storage time on the force and work required for slicing sun-dried bananas.

Storage time	Force (N)	SD (n=3)	Work (N*mm)	SD (n=3)
1 week	47.06 ^a	5.08	227.52 ^a	27.20
4 weeks	46.29 ^a	5.65	207.22 ^a	17.13
8 weeks	45.60 ^a	4.89	163.62 ^a	25.40

For each column, means with the same letter do not differ significantly at $P \leq 0.05$.

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