FOOD AND NON-FOOD UTILIZATION OF CEREALS COMPONENTS

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INTRODUCTION

Several cereals which are well adapted to local conditions are very under-utilized compared to the crops such as maize and wheat. Millets and sorghum are indigenous African cereals well adapted to semi-arid southern Africa. They are drought resistant and produce crops when other cereals fail and are thus critically important grains for food security. Droughts are expected to become more frequent as we enter the “greenhouse age” which further stresses the importance of utilization of these indigenous, drought tolerant crops. Millets are also some of the most nutritious of the common cereals (Belton and Taylor, 2002). As an example, the protein in finger millet apparently has good amounts of the essential amino acids important for human health and growth, such as tryptophan, cysteine and methionine (National Research Council, 1996). In cases of low protein diets, methionine is often one of the amino acids that first become deficient, and the apparently very high content in finger millet therefore makes it especially valuable, not least for people with a vegetarian diet.

Millets and sorghum are primarily grown as subsistence food crops since there is no real market for them (Obilana and Manyasa, 2002). Less than 5% of the annual production of millets and sorghum combined is commercially processed by industry. The production is inconsistent but farmers are reluctant to invest in the crop management necessary for improvements without reliable markets. On the other side, grain processors have little incentive to invest in market development as long as these alternative grains are not more consistently available at competitive prices. This negative trend may be reversed in several ways, e.g. through development of new products and improvement of traditional products based on the under-utilized cereals (Oduori, 2005).

The present paper will focus on two specific new applications based on sorghum: bread from sorghum components (Oom *et al*., 2007) and extracted prolamin protein utilized for food packaging (Enviropak, 2004). Such new applications could create a “market pull” leading to an increased demand and an improved market for the under-utilized grains and new incentives for investments in crop management.

MATERIALS AND METHODS

Kafirin and zein

Kafirin was extracted by CSIR, Pretoria, South Africa from decorticated, condensed tannin-free red sorghum grain using aqueous ethanol plus sodium metabisulphite at elevated temperature by a procedure similar to the industrial processes described for zein by Shukla and Cheryan (2001). Zein was obtained from Sigma-Aldrich (Z3625). Kafirin and zein were defatted by mixing with a fivefold volume of n-hexane during 3 hours at room temperature three times.

Dough formation

Dough-like systems were prepared from the extracted protein as described by Lai and Padua (1997) for zein. Such systems are commonly termed **resins** and were prepared by first dissolving the protein in aqueous ethanol at 75°C and adding oleic acid. The resin was formed by precipitating the protein by addition of distilled water at 5°C (Oom *et al*., 2007).

Protein films and coatings
Films and coatings were prepared by casting from a solution of protein and plasticizers in aqueous ethanol (Taylor *et al*., 2005). The most commonly used plasticizer combination was glycerol, poly(ethylene glycol) and lactic acid (1:1:1). A lipid component was added to some films to induce a controlled phase separation similar to Petersson *et al.* (2005).

RESULTS AND DISSCUSION

Bread from cereal components
The formation of a porous bread structure requires a stable bubble formation during the initial proofing, which in turn depends on sufficient extensional rheological properties of the dough. More precisely, a suitable extensional viscosity preferably combined with strain hardening are required which both have been shown to correlate well with final bread volume for wheat loaves (Wikström and Bohlin, 1999). In wheat dough gluten supplies these extensional rheological properties necessary for the bubble stabilization. Figure 1a shows the extensional viscosity of resins of the prolamin proteins kafirin from sorghum and zein from maize which display the necessary viscosity level as well as strain hardening behaviour required for bubble stabilization. Both kafirin and zein resins display similar bahaviour to that of a gluten resin.

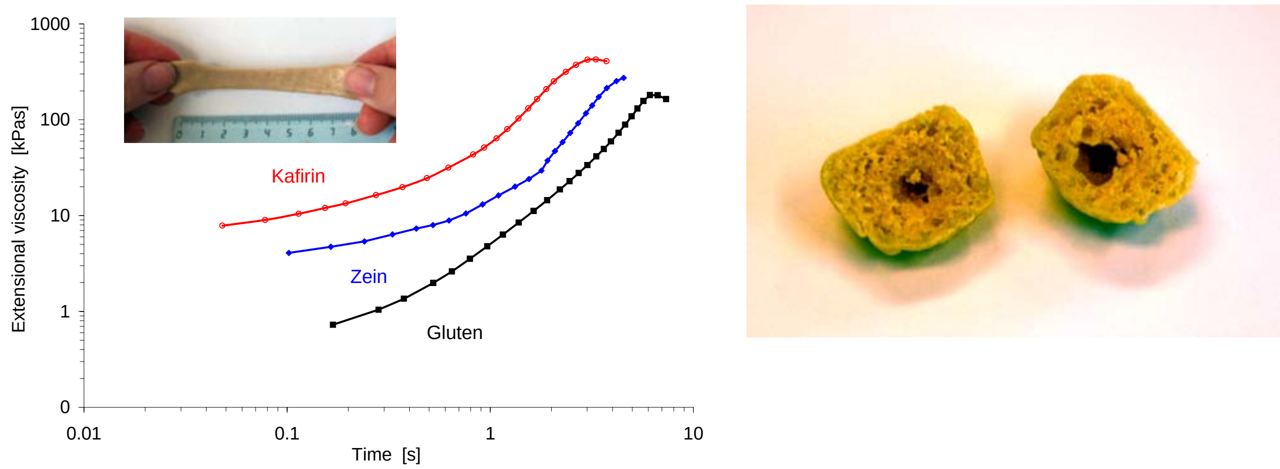

Figure 1. **a)** Growth of extensional viscosity for resins of kafirin, zein and gluten at a constant extension rate of 1.5 s^{-1}. **b)** Bread baked from zein, starch and water.

The zein resin can be mixed with starch to form an “artificial dough” which then can be baked to a bread as shown in Figure 1b. The kafirin resin, however, hardens with time due to disulphide crosslinking of the protein (Oom, *et al*., 2007) preventing mixing with starch into a dough system. Maize flour has previously been mixed with a plasticizer and mixed to a dough at elevated temperature (Lawton, 1992) whereas a similar approach for sorghum has so far failed due to insufficient hydration of the kafirin.

Protein based packaging applications
Kafirin has been extracted from sorghum and used also in packaging applications. The Enviropak project (Enviropak, 2004) was aimed at improving southern Africa's export of fruits and nuts through the improvement of product quality and extension of shelf-life by application of edible coatings with suitable barrier properties. The coatings were manufactured from kafirin extracted

from waste products of the sorghum processing. The project developed extraction and coating procedures and modifications of the protein, thermoplastic processing, sensory evaluation of coated fruits and cashew nuts and controlled release of preservatives from coatings to products.

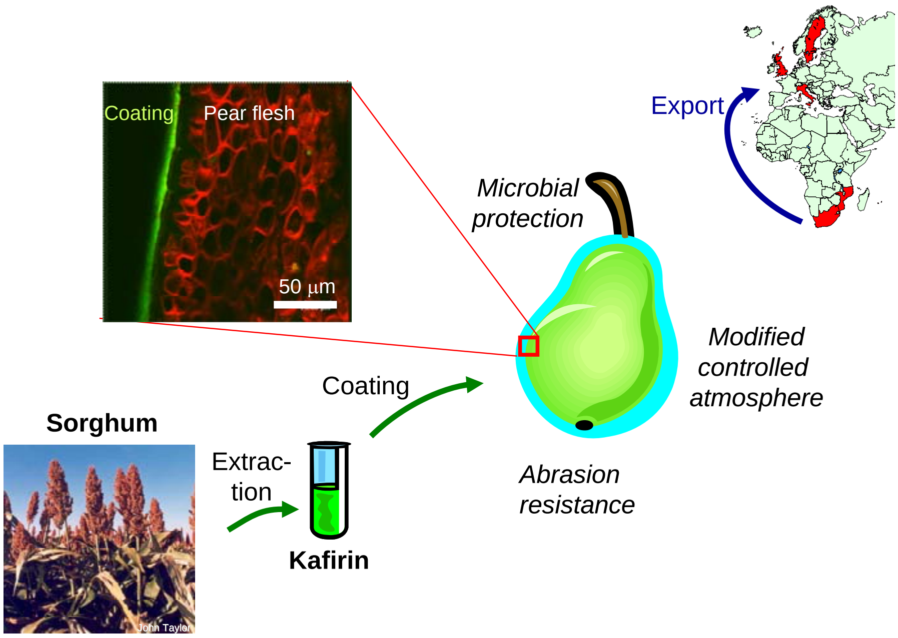

Figure 2. The ENVIROPAK project. Kafirin extracted from sorghum was used to coat fruit and nuts to prolong shelf-life. The coated fruits and nuts were exported from southern Africa to Europe.

Kafirin was extracted on a laboratory scale from a variety of bran fractions from different sorghum varieties and the resulting kafirin could be divided in grades from transparent to yellow and red (Da Silva and Taylor, 2005). The protein was characterized regarding chemical and film forming properties. The extraction was scaled up to pilot scale producing batches of pure kafirin. Various coating formulations of kafirin, pure and modified, and additives were developed to suit the requirements of selected food models, pears, litchi and cashew nuts. The formulation development was based on a complete characterization of the fruit respiration, nut oxidation and the barrier and mechanical properties of kafirin films (Emmambux, *et al*., 2004a,b). Packaging films produced by thermoplastic processing were developed in parallel and its properties characterized (Salerno *et* al., 2007). The coated fruits and nuts were studied regarding shelf-life as well as consumer acceptance and were finally studied under export conditions. Kafirin coatings and films were shown to be very efficient in preserving the quality of fruits and nuts, specifically:

- coatings doubled the shelf life of exported pears and reduce hydrolytic rancidity in coated cashew nuts
- the coatings were highly functional, yet hardly detectable by eye, and was found sensori-cally acceptable even by test panels from southern Africa used to fresh fruits and nuts
- the coatings actively reduced microbial spoilage
- transparent protein films as well as coated paper for packaging and bags could be produced by commercial film blowing and extrusion techniques

A general observation was that there are no general coatings – coatings need to be optimized for each individual product. Kafirin coatings and films are for example highly impermeable to gas (Gillgren and Stading, 2007), but in fact too impermeable for most respiring products like fruits. If a respiring product is coated with an impermeable coating it may switch to anaerobic conditions, decreasing product quality as well as preventing ethylene uptake necessary for ripening. The gas permeability may therefore be regulated by modifying the coating structure to allow for a suitable permeability. Figure 3 shows the permeability of ethylene as a function of addition of a lipid component to an ethylene impermeable protein coating. A mixture of two components of high molecular weight often phase separate which can be used to design a permeable coating structure as shown in the inset of Figure 3 (Petersson *et al.*, 2005). The coating was formed on a permeable fibre carrier and the ethylene permeability increased until reaching the level of the carrier. The permeability was adjustable over a range of four decades allowing to find a suitable level for most respiring products.

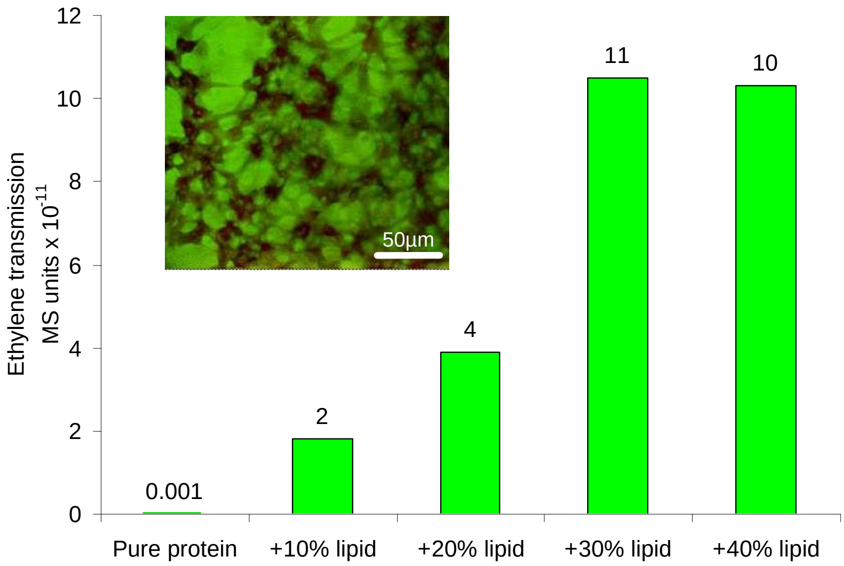

Figure 3. Design of ethylene transmission through a protein coating by controlled phase separation of an added lipid component. The inset shows a CLSM micrograph of a phase separated film.

CONCLUSIONS

A general conclusion is that there are several applications available for indigenous grains and their components other than the traditional ones. These applications may contribute to the necessary "market pull" to increase the demand and improve the market for under-utilized grains. Specific conclusions regarding the presented applications are:

- Sorghum and maize proteins have good extensional rheological properties suitable for baking porous breads. Sorghum flour has poor baking properties, mainly due to poorly hydrated protein and further research is needed to make the protein available.
- Kafirin coatings provide an efficient way to extend the shelf life of respiring oxidation sensitive products.
- All coatings need to be individually optimized to meet the demands of the products coated.

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