HGCA

PROJECT REPORT No. 13

IMPROVING GRAIN PRESENTATION FOR PREDICTING FLOUR YIELD BY IMAGE ANALYSIS

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Improving Grain Presentation for Predicting Flour Yield by Image Analysis

by

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Final report of a three month project commencing 1 May 1989 which was carried out at the Flour Milling and Baking Research Association, Chorleywood. The project was funded with a grant of £12,500 from the Home-Grown Cereals Authority Project No. 0009/1/89).

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Improving grain presentation for predicting flour yield by image analysis

A.D. Evers and R.P. Withey

FLOUR MILLING AND BAKING RESEARCH ASSOCIATION

Final Report

0.25 year project commencing 1 May 1989

ABSTRACT

The project was carried out as an extension to earlier work sponsored by HGCA as Project 0042/1/87, in which image analysis showed promise as a means of predicting flour extraction rate. The natural propgression of the system's development involves further evaluation by application to a larger number of samples.

To facilitate this within a reasonable time-scale a quicker method of presentation was necessary. In the earlier work the presentation of grains to the camera for T.V. imaging involved embedding them in resin and machining of the block to reveal a chosen grain profile. Both the embedding and the machining required considerable skill and time.

The extension of the project has enabled the required new method to be developed. It permits grains to be examined in both elevations provided by the earlier method and in one additional view. The method is both quicker and more precise than its predecessor.

The new method involves alignment of grains along a knife edge, and their retention on a transparent base by adhesive tape. Profiles of whole grains can be recorded before returning the base to the knife for bisection of grains in the plane of the crease. Half grains are maintained in an upright position by a high quality clear tape and re-presented for imaging of the cut face. As in the previous system the grains are handled in groups of ten.

With the benefit of the new method of presentation, relationships between grain morphology and extraction rate are being examined on samples from the 1988 harvest.

OBJECTIVE

To develop a simple method of cutting wheat grains in the plane of the crease, and mounting them for presentation to a T.V. camera.

INTRODUCTION

The project originated from HGCA, Project 0042/1/87, in which wheat grains were imaged in two orientations after embedment in glycol methacrylate resin. For dorso-ventral elevation, grains were examined in blocks as cast. For a sagittal view in the plane of the crease removal of part of the cast by engineer's milling machine was found to be necessary.

Useful correlations were found between grain dimensional relationships and milling extraction rate when 10 widely differing samples were examined. This justified extending the application of the principle to a greater number of samples. Although the embedding method gave fairly satisfactory imaging of grains in both orientations, it was time consuming and demanded some skills and equipment found only in an engineering workshop.

In the extension to the project we have examined simpler alternatives to the embedding method of sample preparation. It has been possible to retain grains in the required position on a register with adhesive tape while being bisected. This report describes the successful system that has emerged from many trials. It consists of several stages, variation of each of which has an effect on others. Some alternatives to the adopted protocol, which were tried and rejected, are briefly described.

MATERIALS AND METHODS

Adhesive tapes

Various types of adhesive tape have been evaluated. Samples for test purposes were provided by DRG Kwikseal Products, Dunstable, to whom we are grateful. The types of tape supplied and used were:-

1. Double sided clear tape - standard product "Sellotape" only.

2. Foam sandwich double sided tape - black and white types - single and double (approx. 1.5mm) thickness.

3. Transfer tapes - tape in which the adhesive is transferred from a paper backing on to a new surface. The new surface can then have another surface or small objects stuck to it. The effect is much the same as double sided tapes but no acetate backing is involved.

4. Single sided clear tape - in addition to standard Sellotape, we received a sample of "Crystal", originally developed for splicing film but now marketed through retail outlets for more general purposes.

The tapes in categories 1-3 above were evaluated for sticking grains to a base for presentation and cutting. Those in category 4 were used as a support for cut grains.

Cutting devices and presentation stages

Jigs for precise alignment of grains, cutting and presenting whole and cut grains to the T.V. camera were made - mainly from perspex - in the engineering workshop at FMBRA.

Blades used in the cutting device were of the Plasplug "Snap-off" type, used in retractable-blade handyman knives.

The diamond-wire saw used was the Testbourne model 850 (Testbourne Ltd., Basingstoke).

RESULTS AND DISCUSSION

The final system is first described as a continuous process. It clearly consists of a series of operations each of which had to be developed by selection of suitable materials and fabrication of suitable devices. Therefore, each stage of the system is reported separately and justification of the selections made are given.

The hardware for cutting and presentation

A diagram of the cutting and alignment device is shown in Figure 1. It consists of:

a) a base, on which grains are aligned in a regularly and uniformly orientated fashion. It is divided longitudinally and the inner face of each side is rebated to allow a blade to pass through the slit formed when the base is assembled.

b) a knife holder in which a blade is supported in such a way that the base can straddle it, and

c) a plunger by which pressure can be applied to the base so that springs below it are compressed, allowing it to be advanced on to the knife edge, thus cutting the grains in half.

Underlying the design of the sytem has been the requirement for versatility. Thus the knife provides both a register for alignment and a cutting edge. Similarly the base provides an anchorage for grains and also serves as part of the stage used for presentation to the T.V. camera.

The manner in which the base fits into the stage is shown in Figure 2. The entire base can be located in two different dispositions at 90^{o} to each other. This permits presentation of dorso-ventral and lateral elevations towards the camera. After the grains have been cut a further presentation of half the base is possible. The geometry of the system is such that the appropriate focal plane for all views is achieved without adjustment of the distance of the stage from the camera. In the half-grain presentation the cut faces are maintained in a common vertical plane by application of clear single sided tape as shown in Figure 3.

The sequence of operations

Alignment

The base is located within the knife holder so that the knife-edge projects through the slot between the two halves. The halves themselves are held together by double sided Sellotape at the non-rebated ends of the base. When the base rests on the extended springs in the cutting device the knife edge projects by about 0.5mm above its surface.

Double-sided Sellotape, applied to the upper surface of both halves of the base holds grains in place as they are aligned along the knife-edge. Ten grains, randomly slected by a grain counter, as described in the previous reports, are aligned, uniformly orientated and consistently spaced, in each set.

The base and set of grains is transfered to the stage so that the dorso-ventral elevation is presented to the camera. Each grain is identified

and imaged. Each image is processed and relevant data sent to disc. As previously described a back-up copy is made through a print-out. The base is reorientated and the lateral image of each grain is acquired, processed and measured in the same way as the dorso-ventral image.

The base is returned to the cutting device, into its earlier position, so that the grains register on the knife-edge. This registration is achieved readily as the base fits snugly between the walls of the knife-holder. Pressure is applied from above by use of the plunger, the grains are cut in the plane of the crease, revealing a cut face profile of the inturned bran in the crease and the endosperm above it. As in the case of the embedded material of the earlier report, the endosperm is stained with iodine/potassium iodide. When dry, a strip of "Crystal" tape is placed along the side of the base corresponding to the cut face of the grains. The half grains are gently pressed into contact with the adhesive surface so that their cut faces are all in a common vertical plane. The half-base is then relocated in the stage for imaging of the cut face. The processing of the image is similar to that used for whole-grain images except that the area of endosperm is also distinguished and measured.

The image and its analysis

The Seescan I.3000 continues to be used. No substantial changes in the company's software, relevant to the analysis used here, have occurred. Task lists have been modified to deal with the images acquired with the new system.

Improvements in the images have come about in several ways: an additional optical filter - a 50mm square gelatine Kodak 44 light blue-green colour filter - is affixed to the screen of the light box and centred on the optical axis. The mask and annulus used for the top view in earlier work is no longer necessary although the upper part of the light box screen is obscured.

The absence of embedding material has allowed production of a clearer image, with improved contrast between bran, background and dyed endosperm.

One outcome of the improvements has been to offer a greater choice of threshold values. With the increased contrast that now exists,

steps representing several grey levels exist at the boundaries of the grain image. The flexibility that this provides comes from the increased range of grey-levels at which a threshold can be selected without substantial alteration of the measured-object size. This is helpful in two ways: it allows the same threshold values to be selected for all elevations, and it permits the selective exclusion of unwanted detail. One such detail is the brush at the opposite end of the grain to the embryo. Brush hair length varies but it is unlikely in the extreme that this variation influences milling extraction rate. In measuring grain length, and angles at the extremities, the brush hairs introduce a misleading hazard. The brush can be removed by sandpapering or by an operator's arbitrary intervention during image processing. These two options were rejected however in favour of a processing solution.

The series of diagrams in Figure 4 show the effects on the image of altering the threshold value over the acceptable range. Being discontinuous and lighter than the rest of the grain, the image of the brush is lighter than that of the rest of the grain. Lowering the upper threshold thus removes the brush from the measured area while still adequately representing the grain shape and size for comparison with others. On lighter grains exclusion of the brush brings about exclusion also of part of the grain image as light or reflective parts of the grain have the same grey values as brush hairs.

Providing that the light patches do not reach the boundaries of the grain image the instruction "fill-holes" can reinstate the lost areas. Since brush hairs occur at a boundary, this processing does not affect their image.

The same thresholds are used in all elevations although the lower one is relevant only to the cut face view. Such consistency facilitates comparison and confirmation of common dimensions on different images of the same grain. In Table 1 the lengths recorded on all these images of grains are shown.

TABLE 1 Lengths (mm) of 10 grains measured in three different presentations

Grain	Dorso/ventral	Lateral	Cut lateral
1	6.738	6.696	6.381
2	5.916	5.965	5.732
3	6.381	6.359	6.25
4	5.829	5.882	5.562
5	5.586	5.663	5.306
6	7.15	7.379	6.439*
7	6.634	6.542	6.107
8	6.734	6.714	6.339
9	6.423	6.23	6.072
10	6.865	6.706	6.523

* This grain was not cut centrally. This was clearly evident from its image and the operator would ensure exclusion of all data for this view from the analysis.

Timing

The time taken, with the new system, to prepare and measure all three elevations of a single grain is approximately 5 minutes. This is a considerable improvement over the previous system and will allow evaluation of the method to proceed at an improved rate.

Other choices

The optimisation of the imaging phase is typical of the process undergone at other phases also. In optimising each phase it has been necessary not only to consider effects on that phase alone, but also on the overall system. Some of the alternatives to the system described above, and the reasons for their rejection are given below:

1. Use of foam sandwich tape for retaining grains on the base.

   It was thought that this would provide a useful cushioning for grains of different sizes, when pressed from the top with a rigid plunger. It was hoped also that grain halves would remain upright after cutting.

   The sandwich tape, though more adhesive than the standard double-sided tape, produced less good results in cutting. Its colour was also undesirable as the imaging of the dorso-ventral elevation would be obtained against a dark ground and thus quite different from the other elevations.

2. Use of sponge rubber below the base in the cutting device.

Before the springs were used in the cutting device, experiments were made with sponge rubber.

The sponge rubber was not sufficiently resistant and was more likely to suffer wear than springs. Foam rubber proved satisfactory when applied to the face of the plunger however as a means of "equalising" grains of different sizes.

3. Choice of optical filters and masks.

Optical filter combinations were tried using existing stocks and specially ordered filters. The pair finally adopted were considerably better than most. Trial and error with various masking profiles on the light box was also used to select the finally adopted system.

4. Cutting grains.

As an alternative to cutting grains with a knife blade experiments were made with a diamond-wire saw. In this intrument a wire band impregnated with diamonds rotates around two pulleys. The pulleys are mounted vertically on a pivoted arm, the disposition of which can be controlled by movement of a counterweight. The cutting is performed by a segment of the wire tensioned between two jockey-wheel guides on the lower side. A tilting stage allows the angle of the specimen in relation the wire to be altered to suit. Although the saw produced clean cuts on sets of ten grains presented to it, the initial cut made was sometimes diverted from the central plane as a result of the ridged profile of the grains. The process was also slower than the alternative and wires tended to break at the welded join.

CONCLUSION

A system of presentation of grains for T.V. imaging has been developed, which is versatile and simple. Conditions have been adopted which permit considerable variation in grain type and orientation to be accommodated without changing operating conditions and without intervention by operator.

In view of the fact that the system is most likely to find application in assessing home-grown and European wheats it is these types which have been used in development of the system. While it is to be hoped that the system is sufficiently versatile to suit third country wheats this has not yet been established.

The new method of preparation will permit a much improved throughput of grains and reduce the time taken in further evaluating the system. A period of five minutes per grain is still too long for the method to be considered, in its entirety, as a routine means of predicting milling extraction rate. It is envisaged that sufficient information will be available from a single elevation for this purpose but at present it is not possible to decide which one will be best. For current evaluation purposes we must continue to collect as much information as possible and thus all three elevations are being measured.

ACKNOWLEDGEMENT

We thank Ian Cox for careful assistance, Alan Leer and his workshop staff for construction of the equipment and Chris Moffet for producing the Figures.

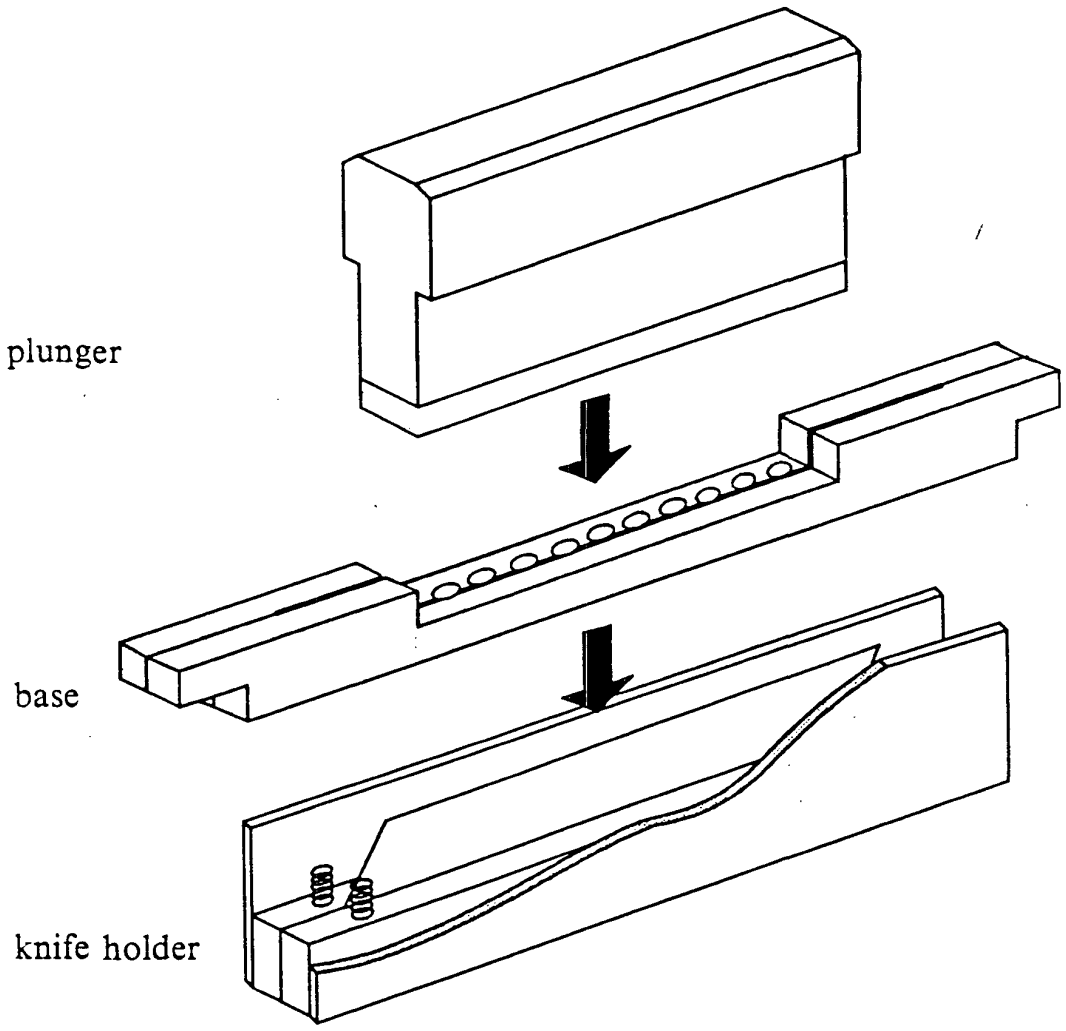


Figure 1 Device for aligning and cutting grains.
For alignment the base rests on the coil springs inside the knife holder.
For cutting, pressure is applied to the base, compressing the springs and advancing the grains on to the knife.

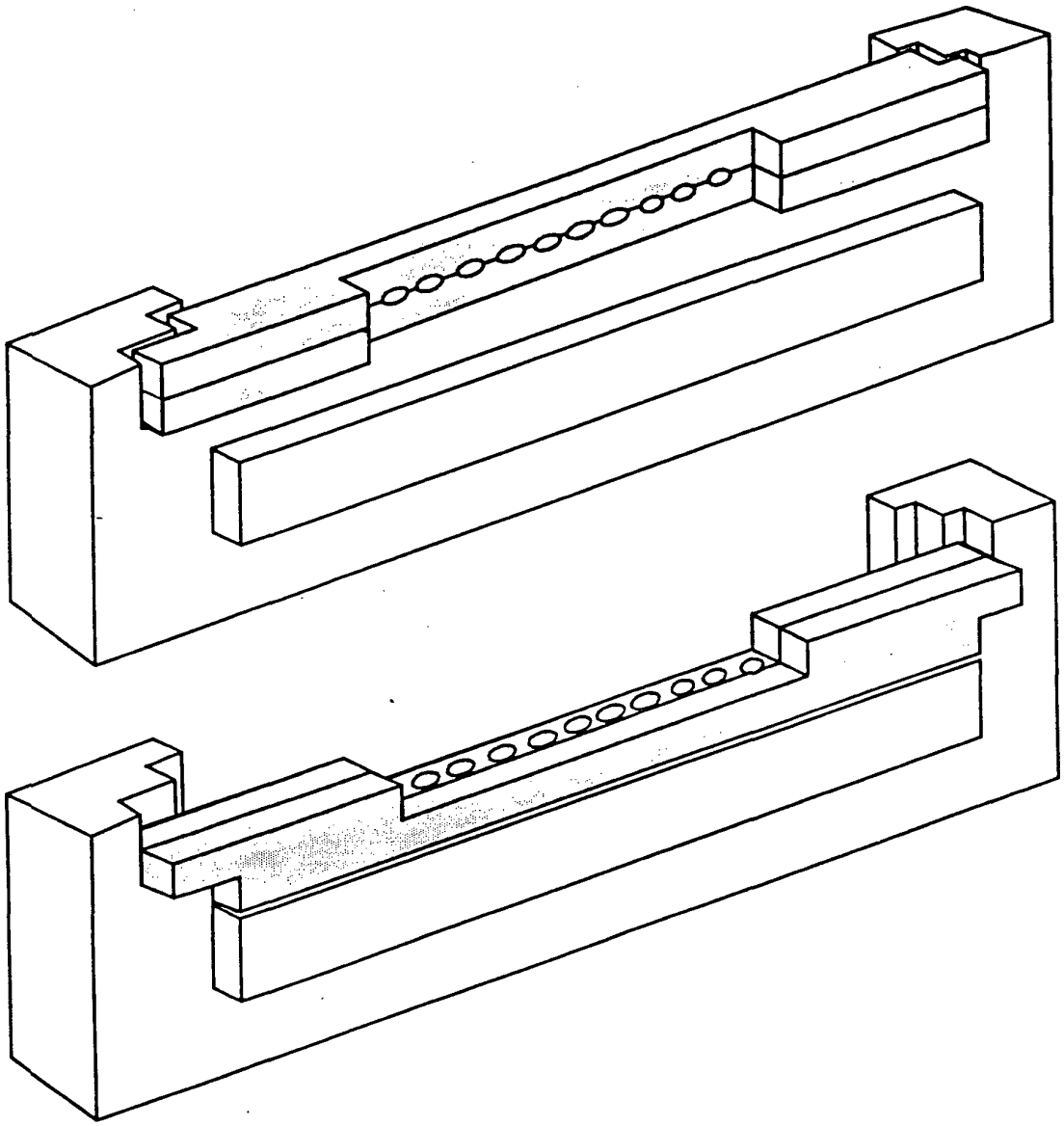


Figure 2 a) Location of base (hatched) in stage for imaging dorso-ventral elevation.
b) Location of base in stage for imaging lateral elevation.

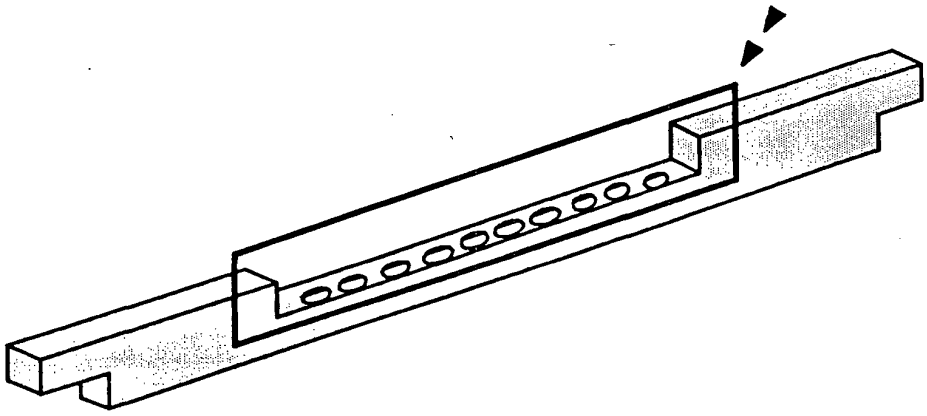
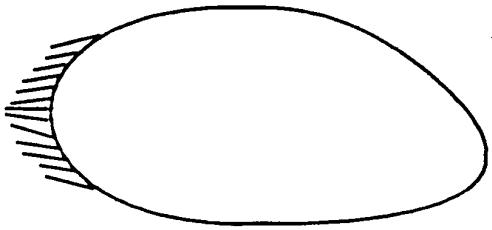
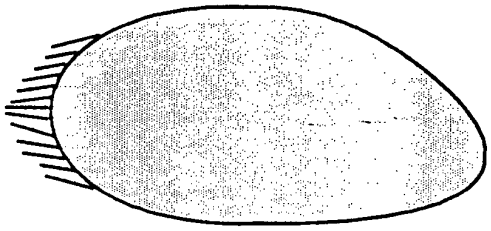


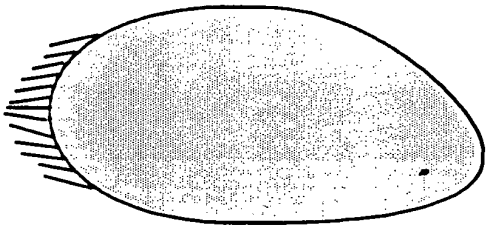
Figure 3 Half-base with strip of Crystal tape (arrows) supporting and aligning cut grains.



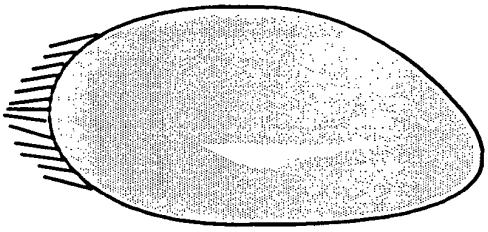
1. Image of grain



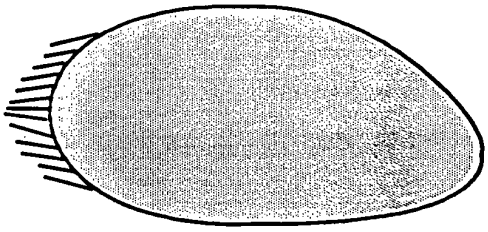
2. Hatched area represents measured area with high threshold value. Note that brush is included.



3. Measured area with lower threshold value. Note that measured area is slightly smaller than grain image - however brush is excluded.



4. Light or reflective patch on threshold image.



5. Threshold image after "Fill Holes" - same as 3.

Figure 4 Method of excluding brush hairs from the measured image