TECHNICAL NOTE

Design and development of a grain kernel singulation device

S. Melvin[1], C. Karunakaran[1], D.S. Jayas[1] and N.D.G. White[2]

[1]*Department of Biosystems Engineering, University of Manitoba, Winnipeg, MB, Canada R3T 5V6; and* [2]*Agriculture and Agri-Food Canada, Cereal Research Centre, Winnipeg, MB, Canada R3T 2M9*

Melvin, S., Karunakaran, C., Jayas, D.S. and White, N.D.G. 2003. **Design and development of a grain kernel singulation device**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **45**: 3.1-3.3. In a cabinet X-ray machine used to detect insect infestations in cereal grains, single grain kernels have to be presented manually on a platform to take X-ray images. Therefore, to automate the sample presentation, a grain kernel singulation device was designed, fabricated, and tested. The singulation device was 60 to 80% efficient in delivering single kernels of Canada Western Red Spring wheat, Canada Western Amber Durum wheat, and barley for taking sequential X-ray images. **Keywords:** X-ray imaging, insect infestation detection, cereal grains, kernel singulation device.

Il est présentement nécessaire de placer manuellement les grains sur une plaque afin de pouvoir détecter les infestations d'insectes lorsque l'on utilise des appareils à rayons X à cette fin. Dams le but d'automatiser l'alimentation des échantillons de grains dans de tels appareils, un mécanisme d'alimentation individuelle a été développé, fabriqué et testé. Ce système a été testé avec du blé Canada Western Red Spring, du blé Canada Western Amber Durum et de l'orge et a il a démontré une efficacité variant entre 60 et 80% lors de la prise séquentielle d'images aux rayons X. **Mots clés**: imagerie à rayons X, détection d'infestations d'insectes, grains de céréales, appareil d'alimentation de grains.

INTRODUCTION

Canada has a zero tolerance for stored-product insects (Canada Grain Act 1975). Grain infested with one or more stored-product insects is not accepted knowingly at any elevator. The complete absence of stored-grain insects is difficult to achieve in practice. In Canada, the Berlese funnel method is currently used in terminal elevators and the Canadian Grain Commission (CGC) inspection offices to detect insect infestations (CIGI 1993). A Berlese funnel uses heat from incandescent light bulbs to extract live insects but it takes 5 to 6 h to detect the presence of insects from a 1-kg grain sample. During this time, the grain may already have been binned in the elevator or loaded on to ships for export (Anonymous 1989). The Berlese funnels are only 49 to 79% efficient in recovering free living adults and only 30% efficient in detecting larval stages of *Cryptolestes ferrugineus* (Stephens), the most common stored-product insect in Canada (Smith 1977; White et al. 1995).

Among different methods that have been investigated, soft X-rays (15 kV and 65 µA) are an efficient method to detect insect infestations in grain (Milner et al. 1952; Stermer 1972; Schatzki and Fine 1988; Haff and Slaughter 1999; Karunakaran et al. 2000). The soft X-ray method detects more than 87 and 96% of wheat kernels infested by larvae and pupae-adults of *C. ferrugineus,* respectively (Karunakaran et al. 2002). In their study, grain kernels were placed manually on the platform in the field of view of the X-ray source and detection system in the X-ray cabinet system (Karunakaran et al. 2002). Therefore, there was a need to fabricate a grain kernel singulation device to automate the sample kernel presentation process within the enclosed shielded box.

Different types of devices have been used to singulate grain kernels for various applications (Casady and Paulsen 1989; Churchill et al. 1991; Jayas et al. 1999). A rotating disc was developed for automatic presentation of up to 50 manually singulated kernels in the field of view of a camera (Churchill et al. 1991). In previous studies, a vacuum apparatus, vibratory bowl, and variable speed conveyors were more than 90% efficient in singulating grain kernels (Casady and Paulsen 1989; Murray 1993; Spewak 1995; Jayas et al. 1999). However, they required bulky air handling systems or substantial physical space. Therefore, these devices cannot be used due to limited space in the enclosure that ensures safety from radiation in the X-ray machine (Model: LX-85708, Lixi Inc., Downers Grove, IL).

The objective of this study was to design, fabricate, and evaluate a simple grain kernel singulation device that can be fitted inside the existing X-ray cabinet system: (maximum available space: length - 270 mm; width - 160 mm; height - 250 mm) and can singulate grain kernels with high efficiency.

CONCEPTUAL DESIGN

The design involved: i) singulation of grain kernels from a bulk sample, and ii) delivery and removal of kernels from the field of view on the sample platform. It was hypothesized that grain kernels could be singulated if a circular disc with oblong holes in the shape of cereal kernels is rotated under a hopper holding a grain sample. The shape and size of holes, and the speed of disc rotation would affect the singulation process. The disc used for singulating the kernels can be used to deliver and remove the grain kernels from the field of view.

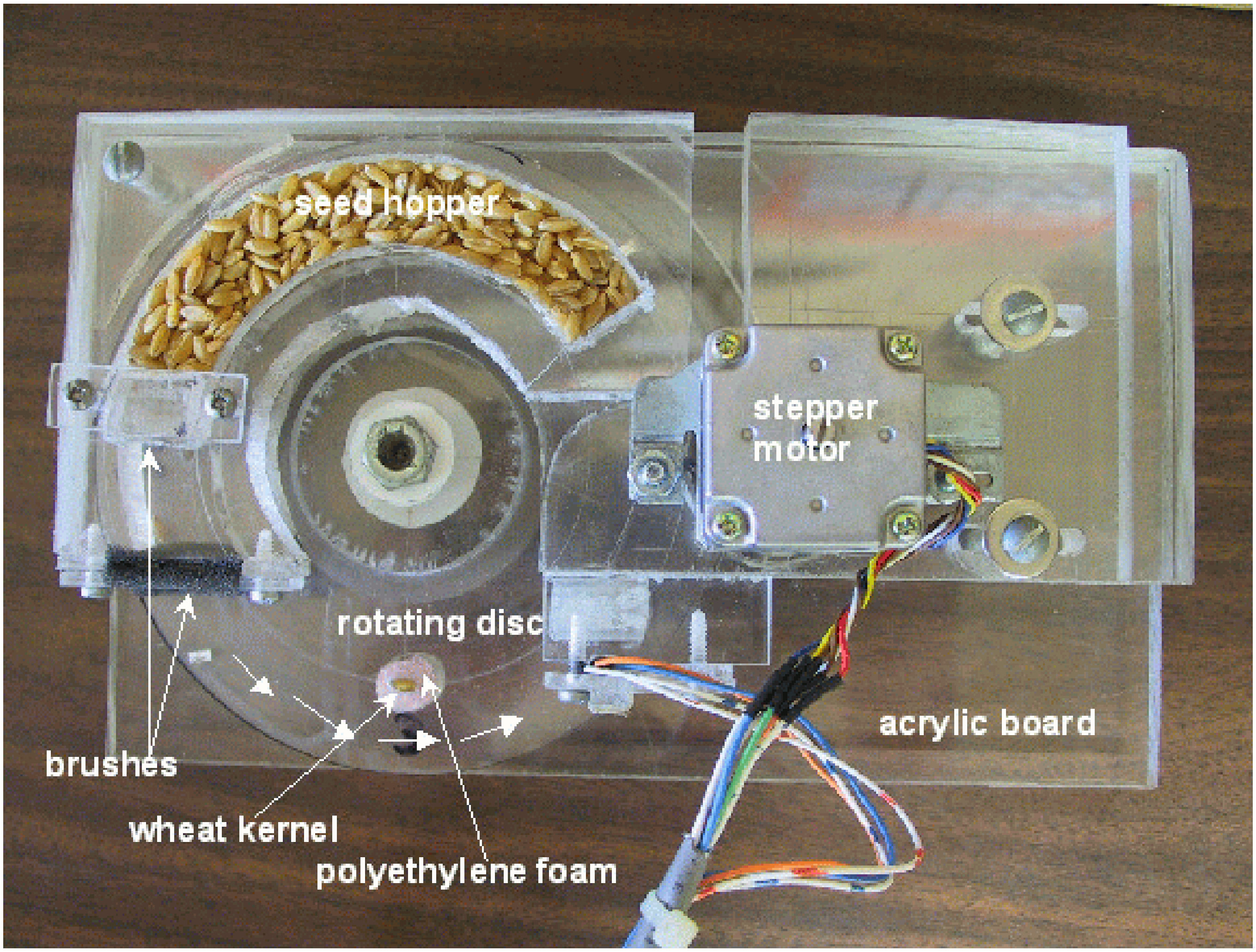

Fig. 1. Grain kernel singulation device.

PROTOTYPE FABRICATION and TESTING

The developed prototype consisted of an acrylic board to which a rotating disc and a semicircular seed hopper were attached (Fig. 1; Melvin 2001). The acrylic board had two 12 mm diameter holes, one filled with 5 mm thick. Polyethylene foam that was transparent to soft X-rays. The rotating disc had oblong holes similar to the grain kernel shape. Various discs, that could be change easily, with different hole sizes were built for different grain types. The oblong holes in the acrylic board and rotating disc were made manually. When the rotating disc moved under the seed hopper, grain kernels were extracted and placed over the polyethylene foam. A stepper motor and an optical sensor were used to turn and stop the disc at appropriate times with the help of reference points on the circular disc. When grain kernels were placed over the polyethylene foam, X-ray images of kernels were acquired and digitally stored, and the disc was rotated. The kernels were removed through the subsequent hole in the acrylic board and were collected in a container kept at the bottom of the acrylic board. A stiff bristle toothbrush and a paintbrush mounted subsequently knocked down kernels extracted in an upright position from the seed hopper and reduced binding of the rotating disc. The software to control the motor was programmed to reverse and vibrate if there was binding of the disc. The control of the singulation device was accomplished through the parallel computer communications port. This design allowed the disc to be controlled by any computer outside the safety cabinet.

The hole size in the disc was selected to extract single kernels from the seed hopper. However, there were instances when no kernel was present in a hole or two kernels were present in the same hole. These instances were easily identified by the image processing algorithm using the histogram feature and area of grain kernels.

RESULTS

The dimensions of the developed prototype were: length – 240 mm; width – 140 mm; and height – 90 mm. Different hole sizes in the rotating disc were tested to determine the efficiency of singulating wheat and barley kernels. The best performance of singulating a clean Canada Western Red Spring wheat sample was achieved when the oblong hole size was 7.0 × 3.0 mm (occurrences of 0, 1, and 2 kernels were 11, 84, and 5%, respectively). With the hole size of 6.0 × 5.0 mm, the occurrences of 0, 1, and 2 kernels were 6, 89, and 5%, respectively, for Canada Western Amber Durum wheat samples. The barley kernels were singulated with 88% efficiency using 6.0 × 5.5 mm hole size (occurrences of 0, 1, and 2 kernels were 8, 88, and 4%, respectively). When the hole sizes were larger than mentioned above, two kernels were extracted either in upright or side by side positions. Conversely, when the hole sizes were smaller, most of the time no kernels were extracted from the hopper. When kernels were presented manually, it required the operator's presence and took nearly an hour for X-raying 100 kernels. The singulation device eliminated the necessity of the operator's presence and the speed of disc rotation determined the time for X-raying grain kernels.

ACKNOWLEDGEMENT

We thank the Natural Sciences and Engineering Research Council of Canada and the Canada Research Chair program for providing financial support for this project. We also thank Mr. Matthew McDonald for his technical assistance.

REFERENCES

Anonymous. 1989. Stored grain regulation. *Supplement to the Official Grain Inspector's Manual*. Winnipeg, MB: Canadian Grain Commission..

Canada Grain Act. 1975. Canada grain regulations. *Canada Gazette* 109: Part II, No. 14.

Casady, W.W. and M.R. Paulsen. 1989. An automated kernel positioning device for computer vision analysis of grain. *Transactions of the ASAE* 32(5):1821-1826.

Churchill, D.B., T.M. Cooper and D.M. Sisland. 1991. Rotating table for measuring seed properties. *Transactions of the ASAE* 34(4):1842-1845.

CIGI. 1993. *Grains and Oilseeds – Handling, Marketing, Processing,* 4th edition. Winnipeg, MB: Canadian International Grains Institute.

Haff, R.F. and D.C. Slaughter. 1999. X-ray inspection of wheat for granary weevils. ASAE Paper No. 99-3060. St. Joseph, MI: ASAE.

Jayas, D.S., C.E. Murray and N.R. Bulley. 1999. An automated seed presentation device for use in machine vision identification of grain. *Canadian Agricultural Engineering* 41 (2):113-118.

Karunakaran, C., D.S. Jayas and N.D.G. White. 2000. Detection of insect infestations in wheat kernels using soft X-rays. CSAE/SCGR Paper No. AFL122. Mansonville, QC: CSAE/SCGR.

Karunakaran, C., D.S. Jayas, and N.D.G. White. 2002. X-ray image analysis to detect infestation due to *Cryptolestes ferrugineus* in stored wheat. In *Proceedings of the Canadian Conference on Electrical and Computer Engineering,* Paper No. 175. Montreal. QC: Canadian Society for Electrical Engineering.

Melvin. S. 2001. Design of a singulation device for presentation of grains to a soft X-ray machine. Unpublished B.Sc thesis. Department of Biosystems Engineering, University of Manitoba, Winnipeg, MB.

Milner, M., M.R. Lee, and R. Katz. 1952. Radiography applied to grain and seeds. *Food Technology* 6:44-45.

Murray, C. 1993. An automated seed presentation device for use in machine vision identification of grain. Unpublished B.Sc thesis. Department of Biosystems Engineering, University of Manitoba, Winnipeg, MB.

Schatzki, T.F. and T.A. Fine. 1988. Analysis of radiograms of wheat kernels for quality control. *Cereal Chemistry* 65(3):233-239.

Smith, L.B. 1977. Efficiency of Berlese-tullgren funnels for removal of the rusty grain beetle, *Cryptolestes ferrugineus*, from wheat samples. *The Canadian Entomologist* 109(4):503-509.

Spewak, R. 1995. An automated seed singulation device for presenting grains to an image processing system. Unpublished B.Sc thesis. Department of Biosystems Engineering, University of Manitoba, Winnipeg, MB.

Stermer, R.A. 1972. Automated X-ray inspection of grain for insect infestation. *Transactions of the ASAE* 15(6):1081-1085.

White, N.D.G., C.J. Demianyk, H. Kawamoto, and R.N. Sinha. 1995. Population growth of *Cryptolestes ferrugineus* (Stephens) and *C. pusillus* (Schonherr) (Coleoptera: Cucujidae) alone, or in competition in stored wheat or maize at different temperatures. *Bulletin of Entomological Research* 85:425-429.