Journal of Cereal Science 64 (2015) 183–188

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Development of an inline measurement technique to assess the quality of wheat dough during the sheeting process

Jyothi Mahadevappa*, Frauke Groß, Rainer Benning, Antonio Delgado

Fluid Mechanics, Department of Chemical and Biological Engineering, Friedrich-Alexander-Universitat Erlangen-Nurnberg (FAU), Cauerstraße 4, 91058 Erlangen, Germany

ARTICLE INFO

Article history:
Received 7 January 2015
Accepted 27 April 2015
Available online 14 May 2015

Keywords:
Wheat dough
Sheeting
Detection of surface cracks
Image processing
Crack ratio

ABSTRACT

Dough sheeting is an important processing operation in the production of various bakery products. The surface cracks on laminated wheat dough are undesirable and generally affect the final quality of the baked products. Although approaches exist for crack detection in the food industry, there is still a need to transfer and adapt it to the desired application especially with respect to inline measurement in the baking field such as dough sheeting. Therefore, the objective of the proposed methodology is to design and develop an inline measurement technique capable of automatic detection and evaluation of the dough surface as well as its measurement in terms of crack ratio. By adapting this technique, different types of dough were tested for their sensitivity to different rolling steps which in turn provides the initial rolling behavior inferences of different dough varieties. The proposed algorithm for the detection of surface cracks is evaluated with various performance measures.

Industrial relevance: The work described in this research is a novel and innovative approach that offers to benefit manufacturers of sheeting equipment in the improvement of equipment design. The bakers owning small and medium-sized enterprises are specially privileged from the successful application of this study, because their competitive capability increases due to the possibility of cost reduction.

1. Introduction

Dough sheeting between the rollers of a sheeting machine is an essential and important processing step towards the production of various bakery products such as biscuits, crackers, cookies, pastries, pizza, pasta, noodles and bread (Qi et al., 2008). The sheeting process has been considered to have an overall impact on the dough behavior during the processing steps, mainly proving, baking and also on the properties of the final products. This further interests in the better understanding of the dough sheeting process (Engmann et al., 2005). On the other hand, knowledge of the surface irregularities such as cracks during the sheeting process will assist in the design and control of dough sheeting operations. As image processing techniques has been proven successful in crack determination of concrete bridges (Adhikari et al., 2014), cracks detection on the surface of rotating eggs (Goodrum and Elster, 1992) etc., here is an attempt to use this successful technique in the investigation of cracks on the dough surface.

The use of digital image processing allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing (Fisher et al., 2006). Image processing techniques and its perspective has provided accuracy, consistency and quality control in the food industry (Du and Sun, 2004; Gunasekaran, 1996; Tillet, 1991). Some of the applications include determination of surface color of food products (Yam and Papadakis, 2004), crack detection in concrete surfaces (Yamaguchi et al., 2008), automation for crack detection on pavement surface images (Subirats et al., 2006), packet detection on the instant noodle packaging production line (Peng et al., 2012), dynamics of bread oven rise by online image analysis (Bai and Zhou, 2006) and analysis of the various states of baking products based on size and color identification (Paquet-Durand et al., 2012).

Although there are many examples of successful applications of image processing techniques in food processing, there is still a need to transfer and adapt it in the sheeting process of the wheat dough which is not yet available. Therefore, the aim of the current work is to develop an inline measurement technique to automatically detect and analyze the surface cracks formed during the dough

* Corresponding author.
E-mail address: jyothi.mahadevappa@fau.de (J. Mahadevappa).

http://dx.doi.org/10.1016/j.jcs.2015.04.013
0733-5210/

sheeting process and thereby classify the dough quality via an inline measurement technique. The experimental results have shown the effectiveness of the developed algorithm in crack detection on the dough surface even without the knowledge of dough composition or its rheological behavior.

2. Materials

Two different dough compositions, ciabatta (dough with yeast) and puff pastry (dough without yeast) are tested using different roll gaps in order to determine the quality of different types of wheat dough after rolling via the developed inline measurement technique.

The two types of flours commercially known as “Brema flour” (wheat flour type 550, produced by Bremer Roland mill Erling GmbH and Co KG, Bremen) and “Keks flour” (cookie flour type 550 produced by Bremer Roland mill Erling GmbH and Co KG, Bremen) are used to prepare the dough samples along with different additives such as oxygen enriched water (80–115 ppm), tap water (2–7 ppm) and cysteine (Merck, Hohenbrunn, Germany). Keks flour has lower levels of gluten proteins and a higher amount of ascorbic acid compared to Brema flour.

2.1. Dough formula and ingredients

Ciabatta dough is prepared according to the following formula: flour 100%, water 56%, salt 1.2%, sugar 10%, yeast 6% and sunflower oil 2%.

Dough for puff pastry is prepared according to the following formula: flour 100%, water 50%, salt 2%, sugar 2% and fat 5%.

2.2. Dough preparation

For experiments, 15 kg dough is mixed using a spiral kneader (Kemper WP ECO 50, Rietberg, Germany). The mixture is manually portioned into approximately 2.5 kg and each portion is sheeted using a sheeting machine (Compas 3000 from Rondo Burgdorf AG, Switzerland) similar to the ones used in small and medium scale baking industries. A sheeting program which is gentle and slow (standard program) consisting of 8 rolling steps (45 mm, 35 mm, 25 mm, 15 mm, 10 mm, 8 mm, 6 mm and 5 mm roll gaps) is used to roll the dough.

Due to the possibility of numerous combinations of dough composition, the dough samples investigated for inline automatic detection and analysis of surface cracks and its quality in the scope of this work are based on the application of statistical design of experiments. The representative dough types are listed in Table 2. The experiments are repeated 4 to 6 times for each and every dough type mentioned in Table 2.

3. Proposed methodology

3.1. Experimental setup

A CCD camera (pco pixelfly vga from pco AG, Kehlheim, Germany) with a resolution of 640 x 480 pixels is installed exactly above the right belt of the sheeting machine for digital image acquisition of the sheeted dough surface. Two light-emitting diode (LED) strip lights are fixed just below the camera on either side of the right belt in order to maintain the brightness of the images and also to keep the images independent of the surrounding lighting.

The setup mainly involves the following steps.

1. The foremost step is to acquire the image of the dough surface using a CCD camera for crack detection. In order to capture the entire dough surface, six images are taken. Depending on the dough thickness and overall size of the dough, images are recorded within the time interval of 0.1–0.2 s.
2. In the next step, acquired images are transferred to the software (image processing algorithm) for further processing. To achieve this, a CCD camera is automated so as to capture images of the dough surface and transfer it to the image processing software. This automation of the camera is done with the help of a pre-installed software called “Camware” and an interface to control it using MATLAB.
3. In the last step, images acquired by the image processing software (implemented in MATLAB) are processed as explained in the image processing algorithm (See Section 3.2) to procure the result which is the crack ratio. Based on this, the final classification of the dough quality can be inferred.

3.2. Image processing algorithm

The steps of processing algorithm are as follows:

1. The first step is to acquire the image of the dough sheet using a CCD camera to analyze the surface cracks. The images are stored in TIF format and processed automatically. Since the algorithm for crack detection can process only gray scale images, RGB images are converted in to gray scale images. Then, in order to improve the contrast and the quality of the image, intensity adjustments are made.
2. The acquired image is then segmented by masking and boundary tracing in order to differentiate the dough surface (ROI) from the background and finally, the image is cropped.
3. Identification of cracks is done using Sobel operators which is a filter for edge detection. Sobel operators are mainly used for computing digital gradients (Gonzalez and Woods, 2008). After applying the Sobel edge detector on the image of the dough surface, a noisy and unwanted result is obtained.

Table 1
Classification of the dough surface without and with the addition of yeast for both Brema flour and Keks flour.

	Condition of the dough surface without yeast	Crack ratio		Condition of the dough surface with yeast	Crack ratio
A.	very large cracks, damaged surface	> 0.55	H	very large cracks, damaged surface	> 0.55
B.	strong cracks, fairly cracked surface	0.45–0.55	I	strong cracks, fairly cracked surface	0.45–0.55
C.	cracked surface	0.30–0.45	J	cracked surface	0.35–0.45
D.	medium, slightly cracked surface	0.25–0.30	K	medium, slightly cracked surface	0.30–0.35
E.	small cracks, good surface	0.15–0.25	L	small cracks, uneven surface	0.20–0.30
F.	very small cracks, very good surface	0.10–0.15	M	very small cracks, good surface	0.15–0.20
G.	no cracks, smooth surface	<0.10	N	no cracks, smooth surface	<0.15