Journal of Food Engineering xxx (2017) 1–8

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Ageing proving cloths – Effects on surfaces and usability

Richard-Sebastian Moeller*, Arvid Duchardt, Hermann Nirschl

Karlsruhe Institute of Technology, Mechanical Process Engineering and Mechanics, Strasse am Forum 8, 76131 Karlsruhe, Germany

ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form
21 April 2017
Accepted 1 July 2017
Available online xxx

Keywords:
Adhesion
Centrifuge method
Fabric
Mechanical ageing
Surface characterization
Wheat dough

ABSTRACT

Proving cloths of polyester, cotton, and a blend thereof were aged by practical use in a bakery, brushing as a moderate, and washing as a thorough cleaning method. The effect on the surfaces in a mechanical respect was recorded by confocal laser scanning microscopy and evaluated according to ISO 25178. The effect on wheat dough adhesive behavior was measured with the centrifuge method and analyzed by tensile strength. Correlations between surface peak properties and adhesion strength as found in a prior work are confirmed for used and stressed materials, and appeared to be more significant than between adhesion and intensity of ageing. While the polyester cloth improved its surface properties and lowered dough adhesion in all cases, cotton (and its blend) did so only in brushing and rather degraded in practical use and washing. Since brushing yielded superior surfaces, it should be installed as inline and everyday cleaning method limiting washing to the hygienically compulsory minimum for maximizing the cloths' service life.

1. Introduction

Drive for labor and cost reduction demands for optimizations in fabrication processes in the bakers' trade. As hygiene is a major issue in food production and large efforts are being made for cleaning, a good potential for improvements and cost reduction is expected especially in the handling of the rather sticky dough. Dough pieces have to rest to prove before baking for which they are put on proving cloths.

These are very common in manual as well as mechanized production because their high rate of air exchange and vapor permeability restrains liquid condensation at the bearing surface and facilitate dough release; low asset cost and traditional use are further reasons. Proving happens at elevated temperatures and high relative humidity (e.g. 30 °C, 90% RH) (Freund, 1995), which are conditions ideal not only for yeast activity, but for mold fungi growth as well. Dough deposition and subsequent deterioration with substantial mold formation exacts frequent cleaning and costly replacement of proving cloths (Adhikari et al., 2001). This can only be avoided or delayed by complete dough piece release, which is regularly enforced only by gravitational force.

As stickiness and dough interaction measures depend on surface properties of the substratum, peel rates or deformation speed, and the dough rheology (Bache and Donald, 1998; Dobraszczyk, 1997), earlier articles on dough–carrier interaction focused on the dough and its intrinsic characteristics (Dobraszczyk, 1997; Heddleson et al., 1994; Hoseney and Smewing, 1999). We investigated the influence of substratum surfaces on adhesion in a prior work (Moeller and Nirschl, 2017) using the centrifuge method, where attention was put on unused materials. Dough adhesion was found to correlate with the surface peak measure Sxp (further reading in Section 2.1), now the question about ageing arose and we expand our work on the dimension of use and wear.

Literature describes several ways to measure adhesion: A direct method records force-displacement-curves and uses the atomic force microscope or the surface force apparatus (Tabor and Winterton, 1969) in microscopic setups (Shimada et al., 2002). A macroscopic implementation for dough adhesion is found in the texture profile analyzer representing the Chen-Hoseney method (Chen and Hoseney, 1995). Unfortunately it instructs a constant deformation speed, which is not representative for practical force driven dough release. Inertia forces are utilized in case of the vibrating disk (Deryagin and Zimon, 1961), drop test (Ermis et al., 2009), or impacting based setups (Wanka et al., 2013); they all share a very short residence time of the actual acceleration and therefore allow only little displacement or deformation before detachment. These techniques are suitable for small particles, hard substances or rather brittle adhesion failure, but not for the soft system of dough on fluffy textiles. The centrifuge method (Krupp, 1967) offers well controlled, even, and long-lasting accelerations

* Corresponding author.
E-mail address: richard-sebastian.moeller@kit.edu (R.-S. Moeller).

http://dx.doi.org/10.1016/j.jfoodeng.2017.07.001
0260-8774/

that induce a constant force in the adherent. It has been employed for adhesion testing of pharmaceutical lactose particles on each other, as well as on metal and plastics surfaces (Podczeck et al., 1996a, 1996b), of microcrystalline cellulose (Nguyen et al., 2010), of salt on wood (Ermis et al., 2011), protein coated super-paramagnetic particles on each other (Knoll et al., 2015) and on polyvinylchloride, cellulose fiber felt, and stainless steel (Knoll and Nirschl, 2014), and of bakery-relevant systems (Moeller and Nirschl, 2017). Our self-designed cuvettes permit large deformations of several millimeters and encase the experiment to protect the dough from drying.

2. Materials and methods

2.1. Surface characterization

All cloths were characterized as described in (Moeller and Nirschl, 2017): 3d surface representations were obtained using a confocal laser scanning microscope (CLSM; VK-X110, Keyence, with 20-fold lens; see Fig. 7), those were analyzed according to ISO 25178 (DIN EN ISO, 2012), which bases upon the material ratio curve (Abbott-Firestone curve, see Fig. 1). The flattest secant spanning 40% defines the kern region; material above constitutes the peaks with their projected surface share Smr1. Material below constitutes the valleys; a measure is the Reduced Valley Depth Svk, which linearizes the valleys' surface share. The Peak Extreme Height Sxp indicates the height of the surface's upper half, and is read off as the height difference between 2.5 and 50% material fraction.

2.2. Dough

Wheat dough is a spongy system of a network of hydrated gluten, starch granules, gas bubbles as the case may be, and a liquid phase. Kneading pursues a desired degree of crosslinking between the gluten molecules. Sample dough was produced to a formula percentage of 160 (mixing 10.0 g flour with 6.0 g water) for adhesion experiments with practically used cloths to establish ties to previous works (Laukemper et al., 2016; Moeller and Nirschl, 2017), or 170 (using 7.0 g water instead) for the other cloths. Wheat flour of type 550 of Rosenmehl brand (Rosenmühle GmbH, Ergolding) was used together with de-ionized water.

2.3. Centrifuge method

A LUMiSizer (LUM GmbH, Berlin) was used as centrifuge together with self-designed transparent cuvettes. The dough sample casts a shadow inside the apparatus, which records the extinction of transmitted light (space- and time-resolved) together with the rotational speed (see Fig. 2). The position of the shadow indicates whether the dough piece still adheres or detached already; it also serves to obtain the centrifugal radius of the sample. Radius and speed determine the centrifugal acceleration. This induces a force in the dough sample instead of compelling a displacement like the texture profile analyzer and allows technological shear rates.

A small sample of dough is extruded and placed on the substratum. A short press-on time of one minute at a relative centrifugal acceleration (RCA) of 19 yielded the contact pressure of an actual-sized dough piece. The contact area was recorded by two perpendicular diameters (approximation as ellipse) with a caliper gauge, and subsequently the dough samples were centrifuged until they detached. Adhesion strength was evaluated by the calculated tension at detachment:

$$\sigma = \frac{F}{A} = \frac{m \cdot r \cdot \omega^2}{\pi/4 \cdot d_1 \cdot d_2}$$

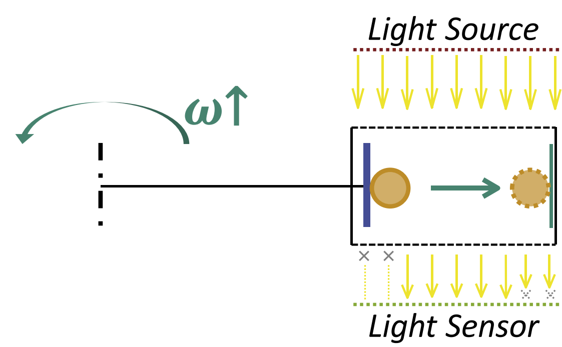

Fig. 2. Scheme of the centrifuge setup: The dough piece casts a shadow, which is recorded.

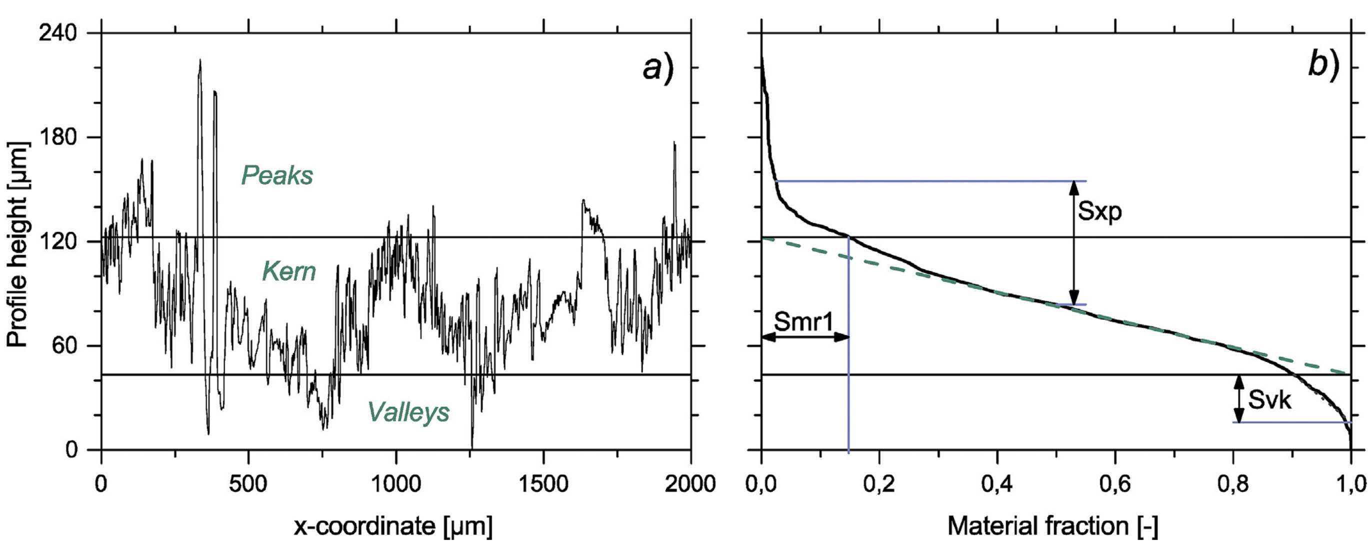

Fig. 1. Surface evaluation according to ISO 25178: From the surface profile (a) the material ratio curve (b) is calculated. The flattest secant spanning 40% defines the kern region; material above constitutes the peaks with their projected surface share Smr1. Peak Extreme Height Sxp is read off as the height difference between 2.5 and 50% material fraction; Svk indicates the Reduced Valley Depth.