The baking potential of wheat-fonio flour composites evaluated by Mixolab

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Abstract

Wheat-fonio flour composites were blended in ratios of 97.5:2.5, 95:5 and 90:10 wt. % using commercial types of both cereal materials, thanks to which the dietary fibre content was elevated stepwise. The basic analytics of the tested composites were depicted by the Zeleny sedimentation test and the Falling Number test, the results of which were not affected by the given enhancement. Mixolab apparatus was employed to evaluate flour rheological behaviour, and the results obtained were statistically compared to laboratory bread-baking test results. During the kneading phase of the Mixolab proof at constant water addition, the increasing fonio portion in the flour composites shortened the time taken to reach consistency maximum softly, clearly lowered this maximum and varied dough stability. Bread volume rose only at a 2.5% fonio flour dosage (from 337 to 402 ml·100 g^{-1}). Higher fonio dosages did not influence specific volumes negatively as compared to the control. Crumb softness as penetration depth corresponded to specific bread volume, and all tested variants demonstrated acceptable sensory profiles. Principal component analysis pointed to connection of the Mixolab features primarily to protein characteristics and behaviour. Furthermore, higher baking potential was statistically proven for a wheat-fonio composite of 95:5; this composite flour could be considered a compromise between dough machinability, consumer quality and the nutritional benefit of fonio.

Fonio flour, Mixolab, PCA, baking test, sensory profile, wheat flour

Introduction

Fonio (*Digitaria* spp.) represents one of the oldest cereals, whose breeding is reaching époque closely to 5 000 years BC. Fonio is classified among grasses (*Poaceae*) and is ranked in the same subfamily as millet. In nature, species fruiting white (*D. exilis* Stapf.) and black (*D. iburu* Stapf.) coloured fonio seeds can be found in the Sahel region of Africa. The local names are 'acha' and 'iburu', respectively, and the former type in particular is typical of Guinea, Mali and Nigeria. In Senegal and Sierra Leone, iburu is cultivated primarily (Emmambux and Taylor 2013). For the majority of the population, fonio represents the staple (and almost the only accessible) food - 2/3 of daily food consumption in Togo and Benin (Jideani et al. 2008). For higher levels of society, wholegrain fonio flour is combined with fine wheat flour.

Composition is similar (Coda et al. 2010) and close to that of wheat regardless of fonio grain colour. Polysaccharides are the principal constituent (75%), followed by proteins (8 – 10%) and fat (1%). The structure of proteins in fonio resembles the α-prolamins of durum wheat (Jideani et al. 1994), while its white variant acha is characterised by a higher content of the prolamin fraction than the glutelin fraction (Coda et al. 2010). In terms of micronutrients, fonio is rich in calcium and phosphorus (Jideani 1999). The tiny seeds are traditionally prepared in the form of porridges, fonio couscous or injera, spongy fermented flat wholegrain bread.

Recipes for wheat biscuits (Ayo and Nkama 2003) and wheat bread (Igyor 2005) have been modified with the use of fonio flour. Fonio flour can also be used as a raw material in multi-composite flour blends, e.g. wheat-fonio-cowpea flour (Olapade and Oluwole 2013).

The aim of the presented work was to describe the effect of three levels of addition of fonio flour on the properties of wheat flour, employing Mixolab apparatus and an internal

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bread-baking trial. Principal component analysis should point to a connection between the behaviour of proteins/polysaccharides and bread quality as affected by the increasing level of fonio flour.

Materials and Methods

Wheat flour (WF) was rendered by the Czech commercial mill Delta Prague (2015 harvest), to average technological quality (protein content 13.0%, Zeleny value 32 ml, Falling Number 400 s). The commercial product "Farine de fonio" (i.e. fonio flour, production year 2015) was sold by the French company Gaia (Graulhet, France). The fonio grains were produced in Burkina Faso, West Africa. On the nutrition label, the producer states 84.0% saccharides, 8.0% proteins and 1.8% fat (in agreement with data published by Coda et al. 2010). The content of total dietary fibre (TDF) was determined analytically for both cereal flour types (3.40% and 5.22%, respectively), and consecutively calculated for the tested flour composites.

Flour composites based on WF were mixed in ratios of 97.5:2.5, 95:5 and 90:10 (w/w) (simplified codes 2.5F, 5F and 10F, respectively). A partial worsening of WF technological quality could be expected due to the increasing proportion of fonio flour.

Basic technological analytics of all samples are expressed by the Zeleny sedimentation value (protein quality) and the Falling Number (estimation of α-amylase activity and the rate of damaged starch) following the internationally approved standards ISO 5529 and ISO 3093, respectively.

The Mixolab test was performed according to ICC standard 173 with constant water addition (61.5% on flour base) and changes in wheat dough rheological behaviour were described during the kneading and pasting phase. Analogically to the farinograph test, the first phase is expressed by torque point C1 (consistency maximum), time of reaching C1 (dough development time), amplitude (curve width), stability of dough consistency (mixing resistance) and torque value C2 (protein weakening by mechanical work and temperature). Similarly to the Amylograph test, the main points of the pasting phase are parameters C3 (starch gelatinisation rate), C4 (hot gel stability), C5 (starch retrogradation rate) and proper temperatures. The repeatability of the test is published on the websites of the equipment producer (Mixolab Applications Handbook 2017).

A bread-baking trial, including sensory evaluation, was performed according to the internal method of the Cereal Laboratory of the UCT Prague (Švec and Hrušková 2010). Leavened dough was prepared using a farinograph according to the following formula: 300.0 g (composite) flour, 12.0 g yeast, 5.1 g salt, 4.5 g sugar, 3.0 g *Perla* margarine (39% fat) and the amount of distilled water necessary to achieve a consistency of 600 Brabender units (BU). The dough mass is fermented for 50 minutes in a thermostat with auto-controlled temperature and humidity (pre-set to 32 °C and 95%, respectively). Dough splitting into 70 g pieces was performed manually as their shaping (moulding) in the form of buns. A full baking sheet was returned to the thermostat for 45 min. leavening. Baking for 14 min. was performed in a laboratory baking oven preheated to 240 °C and steamed immediately after insertion of a baking plate. Bun weight, volume and shape were described objectively after two hours cooling at room conditions. Crumb softness was tested with the use of a PNR-10 penetrometer (Petrotest Instruments, Germany). The sensory profiles of wheat bread and its modifications were assessed by three trained panellists and the results are, therefore, of merely an informative nature.

Data variance and principal component analyses were calculated in Statistica 13 software (Statsoft, USA). ANOVA as an HSD test was expressed at a probability level of P = 95%.

Results and Discussion

Based on comparable botanical ranking and protein structure similarity, not even 10% fonio flour markedly affected the technological quality (Zeleny sedimentation value) of the WF control; the decrease represented ca 10% (Table 1). Fonio flour did not demonstrate

Table 1. The effect of fonio flour on technological analytical features

Flour sample	Zeleny value [ml]	Falling Number [s]	Total dietary fibre [%]
WF	32a	400a	3.40a
2.5F	29a	425a	3.45a
5F	28a	404a	3.49a
10F	27a	384a	3.58a
Repeatability	1	25	0.21

WF – wheat flour; 2.5F – wheat composite flour blended from wheat and fonio flour at a ratio of 97.5:2.5 (w/w). a: means columns marked by the same letter are similar statistically (P = 95%)

higher amylase activity than WF, the Falling Number value of the control (400 s) was reduced by only about 5% (compared to the method repeatability of 10%). In terms of TDF, not even 10% enhancement with fonio represented a verifiable nutritional benefit.

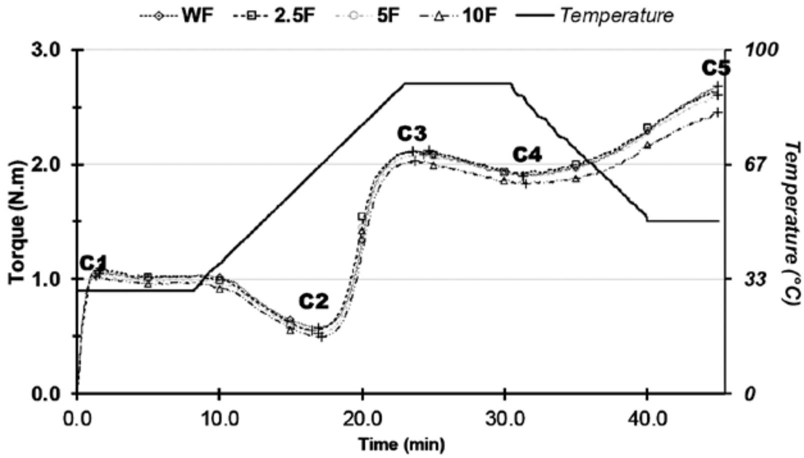

Fig. 1. Influence of fonio flour on Mixolab profile of wheat flour [WF] Example of composite flour coding: 2.5F – wheat-fonio composite flour 97.5:2.5 (w/w); C1 – C5: characteristic torque points

For wheat-fonio composites, Mixolab profiles (Fig. 1) showed a course typical of wheat flour, i.e. the tested alternative cereal material mainly influenced the actual values of C1–C5 torque points. During the kneading phase of the Mixolab test, the tested addition levels demonstrated a different influence – 2.5% of fonio partially improved rheological behaviour, but higher enhancement rates exhibited a reverse effect. The curve of the 5F blend was comparable to the control, while that recorded for 10F was noticeably reduced throughout the test. From a statistical point of view, the affected Mixolab parameters of the flour composite richest in fonio were: the time of C1 (dough development) and energy (overall bakery quality). On the other hand, an increasing amount of fonio slowed starch retrogradation (C5), i.e. a baked product containing fonio should perhaps have a longer shelf life (Table 2). Addition of 25% finger millet caused comparable changes in the wheat flour Mixolab profile (Sharma et al. 2017).

The specific volume of bread prepared from W2.5F was about 20% higher than the control (Fig. 2), meaning that fonio modified the dough's viscoelastic properties to optimal condition for fermentation and gas capture. Bread variants from 5F and 10F attained volumes comparable to the control, perhaps due to gluten 3D-net dilution by fonio prolamins, and standardised leavening time, longer than optima for each of the composite samples. The results published by Igyor (2005) were in agreement with the given finding – they found wheat-acha composite flours of 85:15, 80:20 and 75:25 applicable in practice (product quality comparable to the wheat control). On the other hand, bread shape was influenced equivocally, contra to crumb penetration (Fig. 2).

Analysis of principal components showed that 93% of data variance was explained by the first two principal components (PC1, PC2). As illustrated in Fig. 3, all quality features are located behind a circle expressing quality parameter explanation from 80% at least (with the exception of bread shape BRS). In terms of feature interrelationships, Mixolab

Table 2. The effect of fonio flour on dough rheological behaviour (results of Mixolab test)

Flour sample	Time of C1 [min]	Amplitude [N.m]	Stability [min]	Energy PA [mJ]
WF	1.58	0.08	10.77	131
2.5F	1.65	0.09	10.12	131
5F	1.58	0.08	10.50	128
10F	1.32	0.08	10.37	123
Repeatability	n.d.	n.d.	n.d.	n.d.

Flour sample	Torque point [N.m]				
	C1	C2	C3	C4	C5
WF	1.08a	0.58a	2.12a	1.90a	2.68d
2.5F	1.09a	0.55a	2.12a	1.91a	2.63c
5F	1.04a	0.53a	2.08a	1.90a	2.60b
10F	0.75a	0.50a	1.94a	2.15a	2.45a
Repeatability	n.d.	0.03	0.05	0.03	0.00

WF – wheat flour; 2.5F – wheat-fonio composite flour 97.5:2.5 (w/w); *n.d.* – repeatability not defined in the Mixolab Application Handbook; a-d: means columns marked by the same letter are similar statistically (P = 95%)

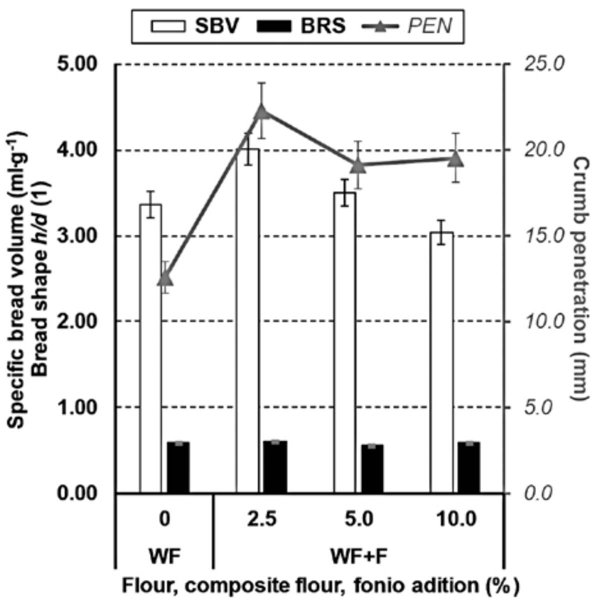

Fig. 2. Influence of fonio flour on baking test results

characteristics together with the Zeleny test and Falling Number could be used for the prediction of baking test results (all parameters located on a positive PC1 semi-axis). Furthermore, torque point C4 is also conjoined to TDF, Falling Number (FN) and recipe water addition (RWA). The distances between tested samples documented qualitative

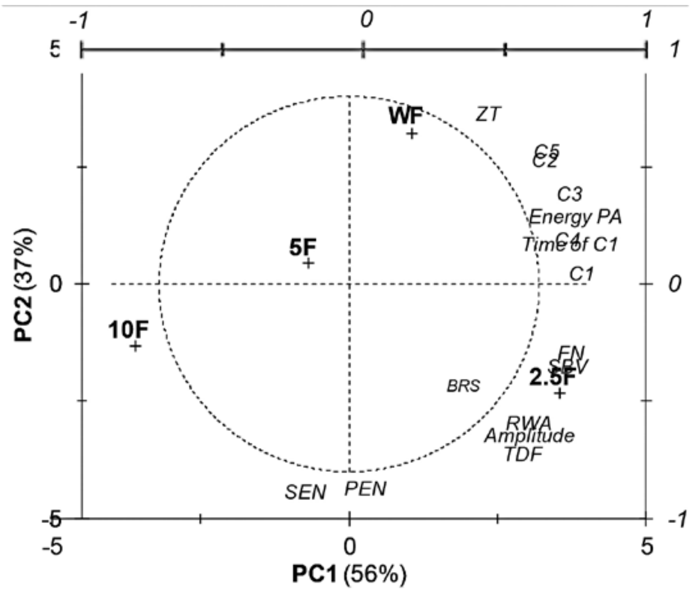

Fig. 3. Biplot of factor scores and loadings
WF – wheat flour; example of composite flour coding: 2.5F – wheat-fonio composite flour 97.5:2.5 (w/w); ZT – Zeleny sedimentation value, FN – Falling Number, TDF – total dietary fibre content; C1 – C5: characteristic torque points of Mixolab curve; RWA – recipe water addition, SBV – specific bread volume, PEN – crumb penetration, SEN – bread sensory profile

similarity, i.e. higher baking potential, for wheat composite flour containing 5% fonio (code 5F).

Conclusions

Enhancing wheat flour with wholegrain fonio flour presumed gradual weakening of non-fermented dough occurred to a small extent as the dosages increased from 2.5% to 10.0%. Pasting behaviour was influenced rather positively – changes in starch gelatinisation rate (C3) and hot gel stability (C4) allowed sufficient production of fermentation gases. In combination with a soft dilution of gluten skeleton in dough, it maintained a specific bread volume of at least the level of the control. A lower starch retrogradation rate (C5) also indicated deceleration of bread ageing. The highest specific bread volume and as well as penetration depth were determined for flour composite 92.7:2.5 (402 as opposed to 337 ml·100 g^{-1}, 22.3 as opposed to 12.6 mm). With respect to the results of principal component analysis, which also reflected dough machinability, a dosage of 5% fonio flour could be recommended in practice (bread volume 350 ml·100 g, penetration 19.1 mm).

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