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Full Length Research paper

Optimisation of raw tooke flour, vital gluten and water absorption in tooke/wheat composite bread: Effect of raw tooke flour and vital gluten on wheat flour physicochemical and dough rheological properties (Part I)

Florence I. Muranga[1,2]*, Martin Mutambuka[1] , Fabian Nabugoomu[3] and M. G. Lindhauer[4]

[1]Department of Food Science and Technology, Makerere University, P. O. Box 7062, Kampala, Uganda.
[2]Presidential Initiative on Banana Industrial Development (PIBID), P. O. Box 32747, Kampala, Uganda.
[3]Faculty of Science and Technology, Uganda Christian University, P. O. Box 4, Mukono, Uganda.
[4]Federal Institute for Food and Nutrition Schutzenberg 12, D-32756 Detmold, Germany.

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Raw Tooke Flour (RTF) is a generic, shelf stable flour from matooke (a cooking banana variety) targeting the baking industry. However, its lack of gluten has hampered development of RTF/wheat composite bread. It is thus necessary to optimize levels of substitution of RTF into wheat flour with vital gluten as a processing aid for improving rheological and baking properties. The specific objective of this study was to determine effect of RTF (0 - 33%) and vital gluten (0 - 3%) on wheat flour pasting and dough rheological properties. The Rapid Visco Analyser was used to measure flour pasting properties while the Farinograph and Extensograph measured dough rheology. Response Surface Methodology (RSM) procedures were used to relate variables to dough rheological properties. RTF significantly increased the pasting profile of wheat flour (by increasing peak, minimum and final viscosities). It weakened the dough (by increasing degree of softening; reducing dough stability and extensibility) while vital gluten strengthened it. Water absorption increased with both variables while dough development time (DDT) was reduced by RTF. Though vital gluten improved dough properties, it did not effectively counteract the negative effects of RTF at the levels applied in the study.

Key words: Composite bread, pasting properties, farinograph, extensograph, RSM.

INTRODUCTION

Uganda is the world's leading producer of cooking bananas (Matooke) (FAO, 2008). Matooke, a triploid acuminata east African highlands (AAA-EA) cooking banana variety makes up the bulk of Uganda's banana production (Karamura et al., 1996). The fruit is bulky and highly perishable thereby facing consistently high post harvest losses of up to 22 - 45% (UBOS, 2001). Raw Tooke Flour (RTF) has been developed (Muranga, 1998) to add value to the crop and improve shelf stability and has found relevant application in the baking and confectionery industry; showing potential to composite with wheat flour in the making of biscuits (Nayiga, 2004), bread (Luwangula, 2004) and cakes (Waiswa, 2004). For compositing with wheat in composite bread production, RTF has been characterised to be rich in starch (80 - 85%^{DB}), with negligible levels of tannins and fibre (Muranga, 1998), a property that has been shown to confer better bread making quality as compared to protein and fibre rich flours (Dendy and Trotter, 1988).

However, RTF is devoid of gluten (the protein that confers the unique bread making properties to wheat) and its addition to wheat affects wheat flour's physicochemical, dough rheological, handling and bread making properties (Luwangula, 2004). On the other hand,

*Corresponding author. E-mail: director@pibid.org. Tel: +256772363271, +256312265789, +256414371050. Fax: +256414340413

Table 1. Design used to study effect of *RTF* and vital gluten on dough rheology.

	Farinograph design		Extensograph design	
Run	Matooke flour (%)	Vital guten (%)	Matooke flour (%)	Vital guten (%)
1	11.00	2.00	11	2
2	16.50	1.50	22	1
3	0.00	1.00	11	0
4	22.00	1.00	22	2
5	16.50	1.50	11	1
6	0.00	0.00	0	0
7	22.00	3.00	11	3
8	11.00	3.00	22	0
9	33.00	2.00	22	3

vital wheat gluten, a by-product of wheat starch extraction process, has been shown to improve rheological/handling properties of slack doughs (Stenvert et al., 1981b; Weipert and Lindhauer, 1999). This study therefore, sought to determine the effect of RTF and vital gluten on wheat flour physicochemical, pasting and rheological properties.

MATERIALS AND METHODS

Material preparation

RTF from Nandigobe, an indigenous triploid Acuminata east African highlands banana variety (Musa AAA-EA) was prepared according to patent No AP/P/2005/003308 (Muranga, 2005). All other baking ingredients were procured locally in Detmold, Germany.

Flour chemical composition

Moisture, crude protein and crude ash were determined according to standard ICC procedures: No. 110, No. 167 and No. 104, respectively (ICC, 2001). Crude fat content was determined by soxhlet extraction using petroleum ether while starch content was determined by an enzymatic hydrolysis procedure using alpha amylase and amyloglucoamylase. The reducing sugars content was determined by the enzymatic bio assay methods developed by R-BIOPHARM (Cat. No. 0716251 and 10716260035).

Flour pasting and dough rheological properties

Flour pasting properties were determined using the Rapid Visco Analyser (Newport Scientific PTY Ltd, NSW, Australia) equipped with Thermocline for Windows 1.2 according to ICC standard No 162 (ICC, 2001). 2.5 g of flour sample was placed into a disposable aluminium vessel along with 25 ml of water and the temperature regime was according to Std 1, running for 13 min. The Falling number test was conducted according to ICC standard No 107 (ICC, 2001) using a Hergen-Perten viscometer (Perten Instruments AB; Huddinge, Sweden). Dough rheological properties was tested with the use of Barbender Farinograph (model 820600; Barbender OHG, Duisburg, Germany) and Barbender Extensograph (Type 860000; Barbender OHG, Duisburg, Germany) according to ICC standards No. 114 and 115 respectively (ICC, 2001).

Experimental designs

Table 1 show D-optimal designs used to study the effect of RTF and vital gluten on Farinograph and Extensograph dough properties. The levels of RTF (x_1) and vital gluten (x_2) varied from 0 - 33 and 0 - 3% respectively.

Data analyses

Data presented as means of replicates were separated by ANOVA while those presented as models were analysed using Response Surface Methodology (RSM) procedures. Design-expert statistical software (DX6.0; Stat-Ease, Inc., MN, USA; 2003) was used in all data analyses.

RESULTS

Flour physicochemical characteristics

Table 2, shows the physicochemical characteristics of wheat flour and RTF as well as the p-value level for the respective components. There were significant ($p<0.05$) differences in the physicochemical characteristics of the two flours with respect to all proximate composition indicators. Moisture content was lower in RTF ($p<0.0001$) whereas starch content was higher in RTF at the same level of significance. Protein and fat were higher in wheat (at $p<0.001$ and $p<0.02$, respectively); on the contrary ash was significantly higher in RTF.

Pasting properties

Figure 1 and Table 3 show the pasting properties of the RTF/wheat composite flours vs. the pure RTF and wheat flour. The two flours exhibited distinctly separate pasting profiles with that of RTF emerging as the most distinct dominant profile and thereby raising the profiles of the composite flour consecutively with increasing level of RTF substitution. Table 3 clearly shows peak, minimum and final viscosity, break down (all at $p<0.0001$) and set

Table 2. Chemical composition of wheat flour and RTF.

Component	Composition^{DB}		P value	SE
	Matooke	Wheat		
Moisture Content (%) (n = 3)	12.36[a]	13.96[b]	<0.0001	0.027
Starch (%) (n = 2)	85.01[b]	69.7[a]	< 0.0001	0.19
Protein (%N × 6.25) (%)(n = 2)	5.57[a]	13.39[b]	0.001	0.24
Fat (%)(n = 3)	0.63[a]	1.15[b]	0.02	0.17
Ash (%)(n = 2)	1.87[b]	0.62[a]	0.0002	0.017
Reducing sugars (mg/100 g)				
Glucose (n = 2)	521.0[b]	71[a]	0.0004	9.02
Fructose (n = 2)	536.5[b]	71[a]	<0.0001	4.53
Sucrose (n = 2)	477[b]	327[a]	0.003	7.62

DB -Dry matter basis, SE-Standard error.
Values in the same row bearing different letters (superscripts) are significantly different.

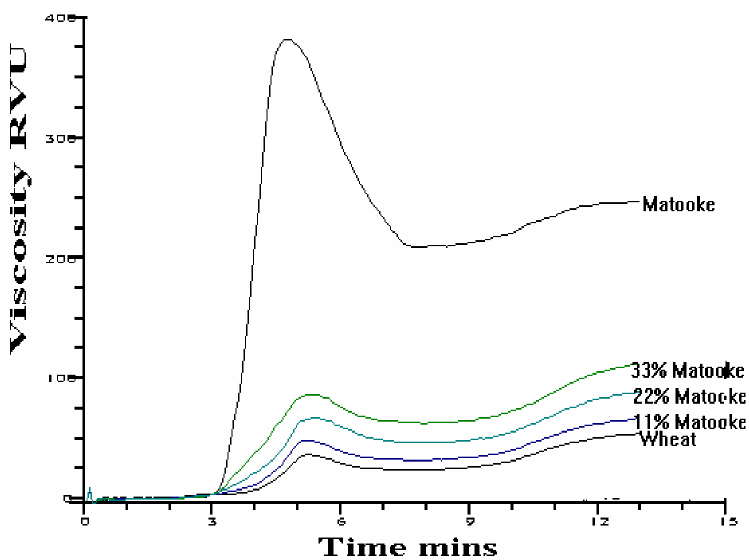

Figure 1. Pasting curves showing effect of RTF (Matooke) on wheat amylographs.

back (at p<0.0156) were significantly higher in RTF than in wheat flour whereas peak time and pasting temperature were significantly lower (at p<0.0015 and p<0.0001 respectively). RTF significantly increased peak, minimum and final viscosity; break down (all at p<0.0001) and set back (p<0.0156) but significantly reduced pasting temperature of the composite flour. However, substitution of wheat with RTF up to 33% did not significantly affect peak time, peak temperature and falling number.

Farinograph and extensonograph properties

The Farinograph measures dough properties in the mixing phase and therefore provides a reliable check for mixing phase and therefore provides a reliable check foruniformity and water absorption capacity of flour, mixing time and dough stability as indicator parameters of dough quality. Figure 2a shows the effect of RTF and vital gluten at 1% on dough rheological properties whereas Table 3 shows all the Farinograph parameters at the respective levels of all the ingredients. Overall water absorption capacity and degree of softening increased with increasing levels of RTF in the composite mixes, whereas the dough stability decreased. The Effect of RTF and vital gluten on rheology of composite dough was investigated through five significant models as follows: for water absorption, dough development time, dough stability, degree of softening and farinograph quality number, respectively. Water absorption, dough

Table 3. Pasting properties of wheat, *RTF* and composite flours.

	Peak viscosity (RVU)	Minimum viscosity (RVU)	Break down[1]	Final viscosit y (RVU)	Setback[2]	Peak time (Min)	Pasting temp (^{0}C)[3]	Peak temp (^{0}C)	Falling no. (Min)
0% Matooke	38.21^{a}	24.96^{a}	13.25^{a}	56.75^{a}	31.79^{a}	5.27^{b}	88.90^{c}	95.13^{a}	344.5^{a}
11% Matooke	48.71^{a}	32.54^{a}	16.17^{b}	67.38^{b}	34.83^{a}	5.27^{b}	87.25^{c}	95.15^{a}	340^{a}
22% Matooke	66.25^{b}	46.04^{b}	20.2^{c}	87.42^{c}	41.37^{a,b}	5.37^{b}	79.95^{b}	95.15^{a}	355^{a}
33% Matooke	88.54^{c}	63.38^{c}	25.17^{d}	113.3^{d}	49.92^{b}	5.40^{b}	75.45^{a}	95.03^{a}	353.5^{a}
100% Matooke	375.92^{d}	201.29^{d}	174.63^{e}	244.7^{e}	43.38^{b}	4.70^{a}	74.73^{a}	94.83^{a}	ND
*P value	< 0.0001	< 0.0001	< 0.0001	< 0.001	0.0156	0.0015	0.0001	0.5376	0.7598
SE	4.40	4.87	1.13	2.63	3.33	0.079	1.10	0.21	16.04
LSD	11.3	12.5	2.9	6.75	8.56	0.2	2.82	0.54	80.28
C.V	3.56	6.62	2.26	2.31	8.27	1.53	1.35	0.22	4.61

n = 3 for all measurements, [1](Peak viscosity minus minimum viscosity) represents granule fragmentation, [2](Final viscosity minus minimum viscosity) represents retrogradation, [3]Temperature where viscosity first increases by at least 2 RVU over a 20 s period (on set), *Each level of RTF substitution was treated as a separate treatment during data analysis, ND-Not determined (the resulting paste was too viscous), SE-Standard Error, LSD-Least significant difference, C.V-Coefficient of variation. Values in the same column bearing different letters (superscripts) are significantly different.

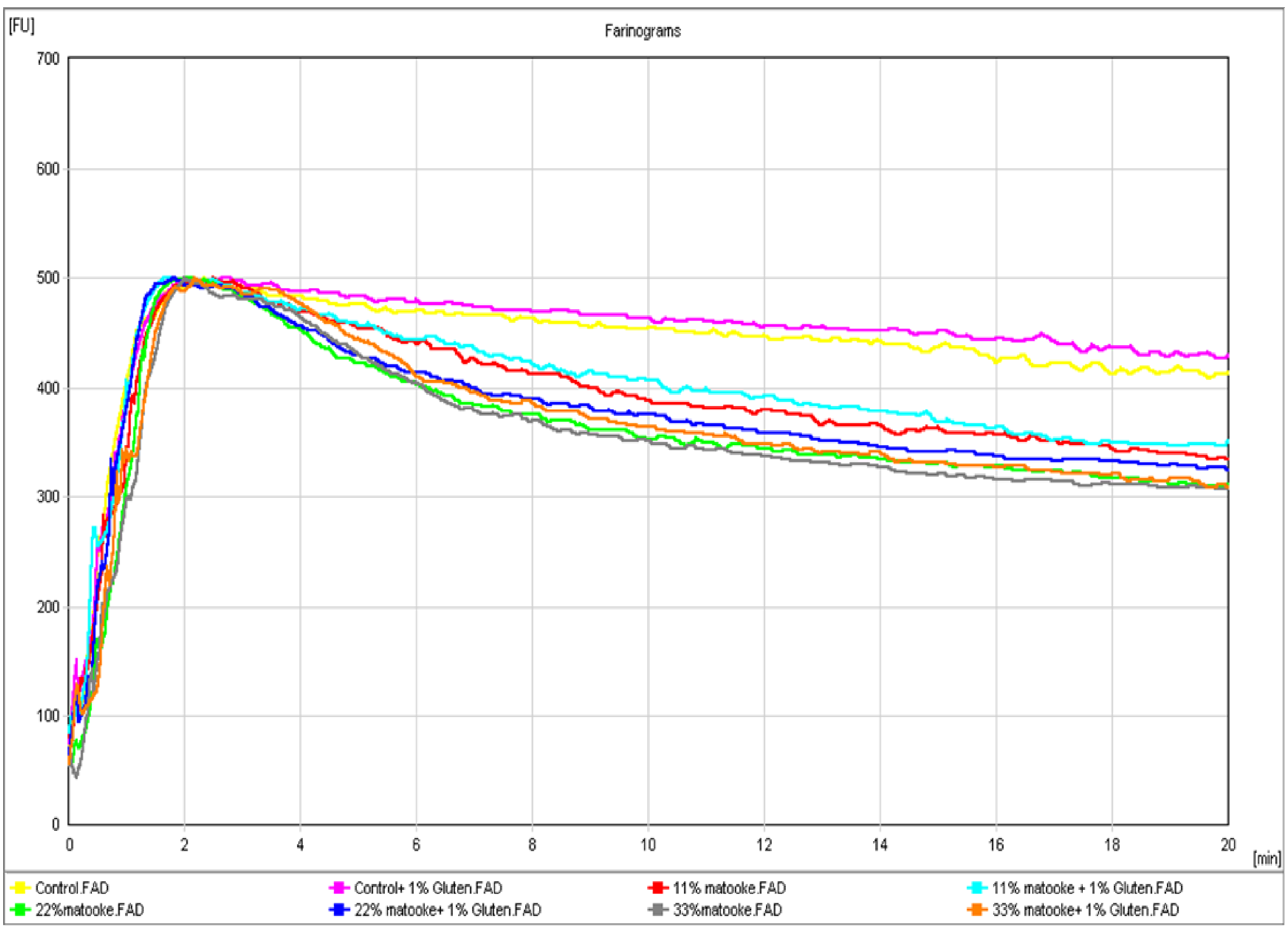

Figure 2a. Farinogram showing effect of RTF (Matooke) and vital gluten (at 1%) on dough rheological properties of wheat flour (control).

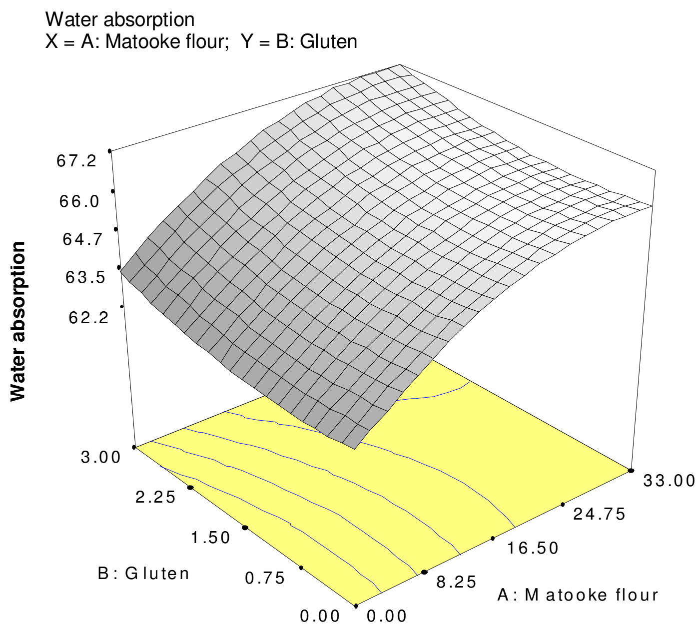

Figure 2b. 3D response surface plot showing effect of RTF and vital Gluten on composite flour's water absorption.

stability and degree of softening were best described by a quadratic model:

$$Y_1 = 62.33 + 0.25x_1 - 0.34x_2 - 0.004x_1^2 + 0.23x_2^2 \ (R^2 = 0.99) \quad (1)$$

Where X_1 is RTF and X_2 is vital gluten.

Figure 2b shows the three dimensional response surface plot showing the effect of RTF and vital gluten on composite flour's water absorption. Water absorption increased with both variables and vital gluten showed significant quadratic effects on water absorption and the model was significant at $p<0.001$. Dough development time (DDT) reduced with increasing levels of RTF in the composite mix. Dough development time under the same variables was described by a linear model (Equation 2). Linear effects on DDT of RTF were significant ($p<0.001$)

$$Y_2 = 2.48 - 0.02x_1 (R^2 = 0.50) \quad (2)$$

Dough stability to mixing reduced with RTF but increased with vital gluten. However, in absence of RTF, vital gluten reduced the stability of wheat flour dough. Vital gluten showed significant linear effects on dough stability (Equation 3). The model was significant at $p<0.001$

$$Y_3 = 8.1 - 0.42x_1 - 1.2x_2 + 0.01x_1^2 + 0.19x_2^2 + 0.03\,x_1x_2 \ (R^2 = 1) \quad (3)$$

Figure 2c shows the three dimensional response surface plot showing effect of RTF (Matooke flour) and vital gluten on composite flour's dough stability.

The degree of softening, a measure of dough break down after reaching full development, increased with increasing RTF but was checked by vital gluten. Interactive effects between RTF and vital gluten were significant ($p<0.001$) in the degree of softening model (Equation 4).

$$Y_4 = 54.40 + 6.98x_1 - 0.11x_1^2 \ (R^2 = 0.95) \quad (4)$$

Linear effects of RTF were significant in all but quality number and its quadratic effect

$$Y_5 = 46.44 \ R^2 = 0 \quad (5)$$

was significant in water absorption and degree of softening. Vital gluten on the other hand showed significant linear and quadratic effects only on water absorption and dough stability.

Extensograph properties

The extensograph determines the extensibility of wheat flour dough by measuring the dough resistance to extension which data when used in compliance with the farinograph enables prediction of the product's baking quality. Figure 3 shows the contrast in the rheological profiles of wheat and that of RTF/wheat/vital gluten composite doughs. The wheat flour had higher values for extensibility with correspondingly lower values for resistance and ratio number in contrast to the composite flours. Table 4 shows significant models ($p < 0.001$)

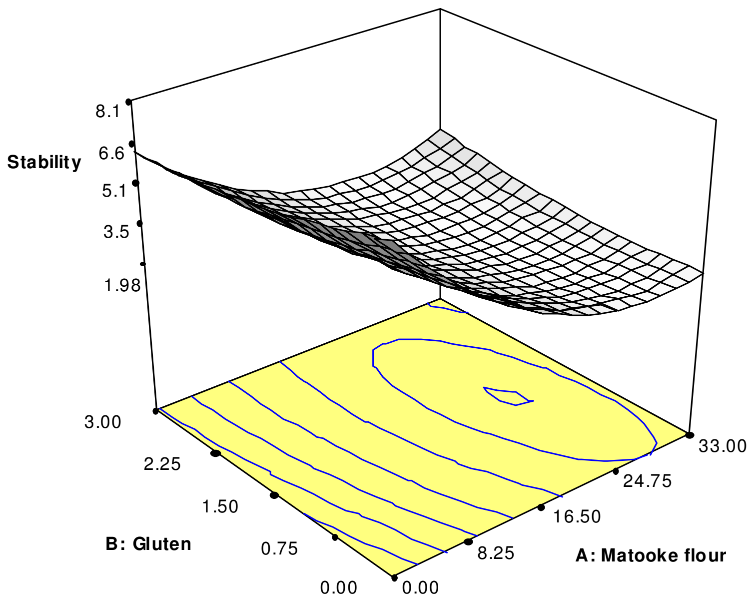

Figure 2c. 3 D response surface plot showing effect of RTF and vital Gluten on composite flour's dough stability.

describing the relationship RTF, vital gluten and composite dough extensonograph properties (after 45 min of dough fermentation). All responses exhibited linear models showing lack of curvature in either effect. The resistance to extension was influenced by vital gluten only, whereas extensibility of the dough and the ratio number depended on RTF alone. Energy on the other hand was influenced by both variables. RTF had a negative effect on both extensibility and energy but had a positive effect on ratio number. Vital gluten exhibited significant positive effects in all models. There were no interactive effects in any of the models.

DISCUSSION

Chemical composition

The most important components of non-wheat flours with respect to bread making potential are starch, fibre and protein. Starchy flours have been shown to perform better than proteinaceous and fibrous flours. The deleterious effect of non wheat protein (and fibre) has been related to introduction of foreign taste and its capacity to disrupt the gluten matrix (Wang et al., 2002). Therefore, the low protein and high starch content of RTF may be advantageous to its bread making potential.

Starch pasting properties

The relationship between flour pasting properties and baking quality of composite flours is not well defined. Pasting temperature of non-wheat starches could be of major importance to bread crumb characteristics with the starch bearing the lowest gelatinization or pasting temperature causing the poorest bread crumb while starches that gelatinize at around the same temperature as wheat are nearly equal to wheat starch in bread making (Bhattacharya et al., 2002; Sanaa and El-Sayed, 2006). On the other hand, a high peak viscosity of the non-wheat flour in composite flours has been reported to result in firm and compact bread (Defloor et al., 1991; Hugo et al., 2003). In this study, RTF reduced pasting temperature and increased peak viscosity, properties that have been shown to negatively affect crumb structure. Therefore the significant increase in values of peak viscosity with increasing level of RTF substitution as well as the significant differences in pasting temperatures RTF and wheat flour must have affected the product quality. Indeed reducing peak viscosity by fermentation of sorghum (Hugo et al., 2003) or addition of malt to wheat-cassava composite flours (Khalil et al., 2000) improves bread making quality of the respective composite flours. A falling number of 200 - 300 has been suggested for optimal bread making performance of composite flour (Khalil et al., 2000) with higher values linked to poor bread making quality. Though RTF did not significantly affect falling number of wheat flour, the falling numbers of both the wheat and the RTF and therefore of the resultant composite flours were higher than that recommended by Khalil et al. (2000), a factor likely to influence baking quality negatively. Therefore, for optimal performance of RTF/wheat composite bread, there is need to modify its pasting temperature and peak viscosity properties. Mature wheat with falling number within the recommended

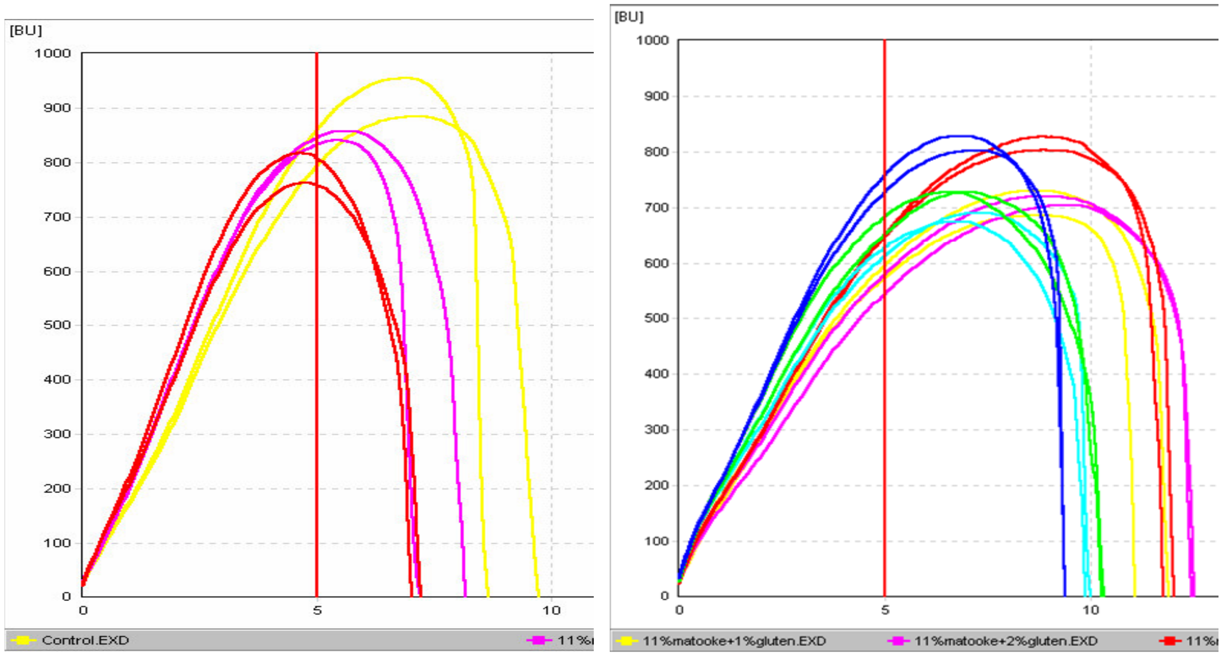

Figure 3. Extensogram showing rheological properties of wheat (control-yellow line) and RTF/wheat/vital gluten composite doughs.

Table 4. Significant models describing the relationship between RTF and vital gluten and composite dough extensograph properties.

Property	Significant model *	R^2
Resistance to extension	$Y_1 = 820.72 + 52.83x_2$	0.7
Extensibility	$Y_2 = 95.06 - 1.19x_1$	0.79
Ratio number	$Y_3 = 9.33 + 0.16x_1$	0.60
Energy	$Y_4 = 102.97 - 2.05\,x_1 + 7.82x_2$	0.91

x1 is RTF and x2 is vital gluten, *models significant at p<0.001.

values should be taken as control and respective interventions should be taken to reduce some of the starch in RTF as per modification in the raw banana flour patent.

Dough rheology

The rheological properties of the dough depend on the quantity and quality of the gluten protein fraction. This is because a certain quantity and quality of gluten proteins must be present for a flour to form a sufficiently cohesive dough so as to trap the gas produced during the fermentation process (Chung and Park, 1997). Therefore, RTF weakened the composite dough whereas vital gluten had a strengthening effect. The weakening effect of foreign flours on wheat flour doughs has been suggested to be consequent to the dilution and/or disruption of the gluten matrix (Lorimer et al., 1991). However, the weakening effect of RTF could have been aggravated by residual sodium metabisulfite, an additive used as a processing aid during the processing of RTF. Sodium metabisulfite is a reducing agent that has been shown to weaken gluten proteins in the dough by cleaving chemical bonds and weakening the gluten network. The dough strengthening effect of vital gluten could be due to its visco-elastic characteristics resembling those of native gluten. Added gluten becomes an integral part of the overall gluten network by interacting with the flour's endogenous gluten during mixing (Callejo, 1999).

The increased water absorption of composite flour can be related to the high water absorption capacities of dry gluten (Weipert and Lindhauer, 1999) and RTF (Muranga, 1998). The effect of vital gluten on DDT may be due to the fact that vital gluten develops more slowly than endogenous gluten and slows down the overall gluten development within the dough (Callejo, 1999). The slow development of vital gluten may also explain its positive effect on extensograph area under curve and the R/E ratio parameters, effects that were observed by Weipert and Lindhauer (1999).

However, presence of RTF seemed to diminish the effect of vital gluten on DDT, though the interaction was not statistically significant. This phenomenon could be related to the effect, on vital gluten, of residual sodium metabisulfite (Callejo, 1999). Sodium metabisulfite acts by reducing the time required to develop dry vital gluten so that both the added and endogenous gluten attained optimum development at the same time. The same phenomena could explain RTF's negative effect on extensograph area under the curve, resistance to extension and extensibility parameters.

CONCLUSION

RTF has potential for bread making due to its high starch (and low protein) content and high water absorption capacity. However, RTF has a significant effect on the pasting properties of wheat flour which could affect its bread making potential. Reducing peak viscosity of RTF by adapting modifications of the raw banana flour patent should be undertaken and tested for potential improvements in bread making quality.

Residual sodium metabisulfite in RTF may be helpful in improving vitality of vital gluten (when the latter is used as improver) but flour with high sodium metabisulfite levels should be avoided in absence of vital gluten. By improving rheological properties of RTF/wheat dough, vital gluten could be an effective improver in wheat/RTF composite bread. This improving effect is important for machinability and workability of the composite dough, and during proofing and baking, gas retention and subsequent improved loaf volume and crumb structure/texture.

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