

Supplementary material

Table S1: Effects of compositing wheat flour with untreated; 53% moisture and heat-treated Bambara on the dough proofing characteristics of the composite dough.

Moisture Content	Heat Treatment Method	Flour Replacement	Hm(mm)	H'm (mm)	T1 (min)	T'1 (min)	Tx (min)	Gas retention coefficient (%)
Wheat		0	41.8 ^a (2.5)	58.0 ^a (5.2)	89.3 ^c (3.2)	101.3 ^b (2.5)	57.7 ^c (1.9)	69.7 ^d (1.9)
Raw untreated		15	14.5 ^e (0.4)	37.6 ^f (2.0)	182 ^b (1.0)	137.3 ^f (1.5)	87.9 ^b (1.5)	82.9 ^g (1.5)
Raw untreated		30	24.1 ^b (0.8)	36.2 ^f (0.8)	173.6 ^c (1.1)	180 ^g (0.0)	83.3 ^c (0.7)	83.3 ^f (0.7)
53%		15	13.1 ^f (0.9)	36.4 ^f (0.9)	180 ^a (0.0)	136 ^d (3.6)	84.3 ^c (1.9)	80.0 ^c (1.5)
		30	22.7 ^c (0.3)	38.3 ^f (0.9)	171.6 ^d (2.0)	179.67 ^g (1.5)	80.7 ^d (0.5)	80.7 ^e (0.5)
	Infrared	15	13.4 ^e (2.0)	48.2 ^c (2.4)	180 ^a (0.0)	159.3 ^d (5.8)	80.0 ^d (1.5)	69.7 ^d (3.6)
		30	19 ^{cd} (1.9)	57.4 ^a (3.0)	178.6 ^{ab} (1.2)	74.3 ^a (5.0)	69.7 ^c (3.6)	84.3 ^f (1.9)
	Microwave	15	17.2 ^{cd} (1.1)	30.6 ^g (2.1)	172 ^c (5.2)	170.6 ^f (5.6)	92.4 ^a (2.9)	92.4 ^h (2.9)
		30	21.3 ^c (1.9)	36.2 ^f (0.8)	178.1 ^{ab} (1.5)	167.3 ^f (5.8)	87.4 ^b (1.9)	87.4 ^g (1.9)
	Combined	15	13.6 ^c (3.1)	39.0 ^c (0.2)	180 ^a (0.0)	173.3 ^f (9.0)	89.3 ^a (3.5)	83.8 ^f (1.3)
		30	20.1 ^c (1.4)	32.7 ^g (2.0)	174 ^{ab} (4.5)	178.31 ^g (2.8)	83.8 ^c (1.3)	89.3 ^h (3.5)

Means of 3 replicate experiments and standard deviations of heat treated and untreated Bambara flours substitutes at 15 and 30%. Hm Maximum dough height; H'm Maximum height of gaseous production; T1 Time at which dough reaches the maximum height; T'1 Time of maximum gas formation; Tx Time at which gas starts to escape from the dough. Mean values in a column with different superscripts letters differ significantly ($p < 0.05$).

Table S2: Four parameter Burgers model showing effects of compositing wheat flour with untreated; 53% moisture and heat-treated Bambara on the creep and recovery dough rheological properties of the composite dough

Moisture Level	Heat treatment	Flour replacement	Creep				Recovery			
			J_0 (1/Pa) x 10^{-5}	η_0 (Pa.s) x 10^5	J_1 (1/Pa) x 10^{-5}	λ (s)	J_{0R} (1/Pa) x 10^{-5}	J_{1R} (1/Pa) x 10^{-5}	λ_R (s)	
Wheat		0	2.78 ^a (0.06)	1.62 ^a (0.07)	9.56 ^b (1.23)	0.22 ^d (0.04)	2.61 ^d (0.12)	7.03 ^a (0.14)	0.31 ^c (0.08)	
RUT		15	2.22 ^b (0.12)	1.39 ^d (0.03)	8.31 ^c (1.33)	0.23 ^c (0.02)	2.18 ^c (0.11)	5.17 ^b (0.23)	0.34 ^c (0.06)	
RUT		30	2.05 ^a (0.14)	1.25 ^a (0.12)	8.80 ^c (1.72)	0.26 ^c (0.01)	1.56 ^a (1.05)	3.03 ^c (0.62)	0.41 ^a (0.01)	
53%		15	2.23 ^b (0.14)	1.40 ^b (0.24)	8.30 ^c (3.57)	0.29 ^b (0.05)	2.19 ^c (0.21)	5.15 ^b (0.11)	0.35 ^c (0.08)	
		30	2.17 ^a (0.22)	1.18 ^f (0.13)	8.75 ^d (0.85)	0.32 ^a (0.01)	1.55 ^a (0.34)	3.07 ^c (0.14)	0.26 ^d (0.05)	
	Infrared	15	2.35 ^c (0.30)	1.15 ^f (0.20)	8.67 ^d (2.10)	0.32 ^a (0.05)	2.41 ^f (0.43)	5.43 ^c (0.40)	0.45 ^a (0.03)	
		30	2.01 ^a (0.21)	1.18 ^f (0.15)	7.78 ^d (3.51)	0.32 ^a (0.13)	1.80 ^c (0.30)	3.37 ^a (0.62)	0.33 ^c (0.12)	
	Microwave	15	2.33 ^c (0.33)	1.42 ^c (0.21)	7.82 ^c (1.68)	0.36 ^a (0.02)	2.34 ^f (0.13)	5.32 ^c (0.52)	0.37 ^b (0.07)	
		30	1.89 ^a (0.31)	1.25 ^c (0.11)	8.37 ^c (2.71)	0.35 ^a (0.04)	1.75 ^b (0.17)	3.33 ^a (0.27)	0.39 ^b (0.04)	
	Combined	15	2.24 ^b (0.05)	1.61 ^a (0.19)	8.81 ^c (1.52)	0.33 ^a (0.03)	2.17 ^c (0.20)	5.39 ^c (0.32)	0.36 ^b (0.10)	
		30	1.57 ^f (0.43)	1.54 ^b (0.14)	9.84 ^a (2.81)	0.34 ^a (0.01)	1.73 ^b (0.54)	2.97 ^d (0.54)	0.34 ^c (0.50)	

J_0 , the instantaneous elastic compliance; η_0 , the zero-shear viscosity; J_1 , the retarded elastic compliance; λ , the retardation time and their counterparts during the recovery phase.

Mean values in a column with different letters differ significantly ($p < 0.05$)

Table S3: Effects of compositing wheat flour with untreated; 53% moisture and heat-treated Bambara on the soluble and insoluble fiber and SDS sedimentation values. Wheat flour and heat treated, and untreated Bambara flour substituted at 15 and 30% to make composite flour doughs

Moisture Content	Heat Treatment		Flour Replacement	Insoluble Fiber (%)	Soluble Fiber (%)	SDS Sedimentation (ml)
	Method					
Wheat			0	2.27 ^c (0.12)	0.12 ^d (0.022)	53.67 ^a (0.57)
Raw untreated			15	2.42 ^d (0.05)	0.16 ^e (0.052)	41.33 ^b (1.52)
Raw untreated			30	2.87 ^b (0.13)	0.28 ^d (0.001)	25.66 ^f (0.55)
53%			15	2.43 ^d (0.09)	0.15 ^c (0.006)	40 ^b (0.9)
			30	2.99 ^b (0.22)	0.23 ^e (0.012)	25.66 ^f (0.57)
	Infrared		15	2.45 ^c (0.15)	0.25 ^e (0.450)	46 ^b (1.0)
			30	2.93 ^b (0.03)	0.31 ^d (0.010)	30.33 ^e (0.55)
	Microwave		15	2.50 ^c (0.09)	0.29 ^e (0.052)	41.67 ^c (0.35)
			30	3.02 ^a (0.086)	0.35 ^d (0.003)	29.33 ^e (0.75)
	Combined		15	2.62 ^c (0.54)	0.24 ^d (0.007)	38.33 ^d (0.35)
			30	3.21 ^a (0.23)	0.42 ^d (0.007)	27.67 ^c (0.73)

Mean values in a column with different letters differ significantly ($p < 0.05$).

Table S4: Effects of compositing wheat flour with untreated; 53% moisture and heat-treated Bambara on the Bread physical characteristics: mass, volume and specific volume of wheat flour and flours resulting from untreated; 20% and 53% moisture and heat-treated Bambara. Wheat flour and heat treated, and untreated Bambara flour substituted at 15 and 30% to make composite flour doughs.

Moisture Content	Heat Treatment Method	Flour Replacement	Mass(g)	Volume (cm3)	Specific Volume (g/(cm3))
Wheat		0	322 ^c (2)	859.67 ^j (1.52)	2.6 ^l (0.02)
Raw untreated		15	324.33 ^d (1.17)	751.67 ^g (3.05)	2.37 ^h (0.02)
Raw untreated		30	336.17 ^f (1.53)	557 ^a (3)	1.63 ^a (0.07)
53%		15	327 ^e (1)	790.33 ^j (2.61)	2.49 ⁱ (0.92)
		30	335 ^e ^f (2)	567 ^{ab} (4.50)	1.66 ^a (0.42)
	Infrared	15	320.13 ^e (1.52)	811 ^k (3.60)	2.57 ^k (0.02)
		30	312.67 ^a (2.08)	689.33 ^f (5.16)	2.28 ^g (0.08)
	Microwave	15	321 ^c (1)	795.66 ^j (5.87)	2.47 ^j (0.03)
		30	310.33 ^a (2.30)	662 ^e (1.35)	2.13 ^f (0.07)
	Combined	15	312.67 ^a (2.51)	761.66 ^h (3.05)	2.41 ⁱ (0.04)
		30	312.66 ^a (2.56)	594.66 ^b (5.50)	2.04 ^e (0.19)

Mean values in a column with different letters differ significantly (p <0.05).

Table S5: Effects of compositing wheat flour with untreated; 53% moisture and heat-treated Bambara on the bread textural characteristics. Wheat flour and heat treated, and untreated Bambara flour substituted at 15 and 30% to make composite bread

Moisture Content	Heat Treatment Method	Flour Replacement	Firmness (N)	Adhesiveness (N)	Cohesiveness	Springiness	Chewiness
Wheat		0	10.72 ^a (3.2)	0.72 ^g (1.32)	0.28 ^g (0.03)	203.06 (31.79)	28.62 (4.42)
Raw untreated		15	25.64 ^g (4.05)	-0.12 ^b (0.02)	0.15 ^d (0.01)	40.74 (3.66)	68.43 (5.63)
Raw untreated		30	31.09 ^f (3.90)	-0.11 ^b (0.01)	0.18 ^e (0.01)	50.09 (4.78)	64.20 (6.21)
53%		15	16.29 ^{bc} (4.07)	-0.13 ^d (0.00)	0.26 ^g (0.02)	128.54 (9.62)	46.17 (2.06)
		30	28.03 ^d (7.67)	-0.13 ^d (0.00)	0.31 ^{gh} (0.0)	61.09 (5.03)	107.48 (34.25)
	Infrared	15	15.28 ^b (3.64)	-0.13 ^d (0.00)	0.12 ^c (0.02)	118.66 (27.25)	17.22 (2.79)
		30	15.21 ^b (1.92)	-0.013 ^a (0.0)	0.26 ^g (0.02)	128.77 (22.04)	39.88 (4.37)
	Microwave	15	20.43 ^c (2.02)	-0.14 ^e (0.026)	0.38 ^h (0.02)	98.54 (5.05)	78.78 (8.95)
		30	13.47 ^b (2.03)	-0.12 ^c (0.00)	0.26 ^g (0.02)	153.38 (9.79)	37.70 (3.15)
	Combined	15	17.19 ^{bc} (3.78)	-0.14 ^e (0.015)	0.10 ^b (0.00)	99.14 (8.27)	38.94 (6.01)
		30	14.96 ^b (1.667)	-0.12 ^c (0.004)	0.05 ^a (0.00)	211.91 (7.02)	35.13 (2.97)

Mean values in a column with different letters differ significantly (p < 0.05).

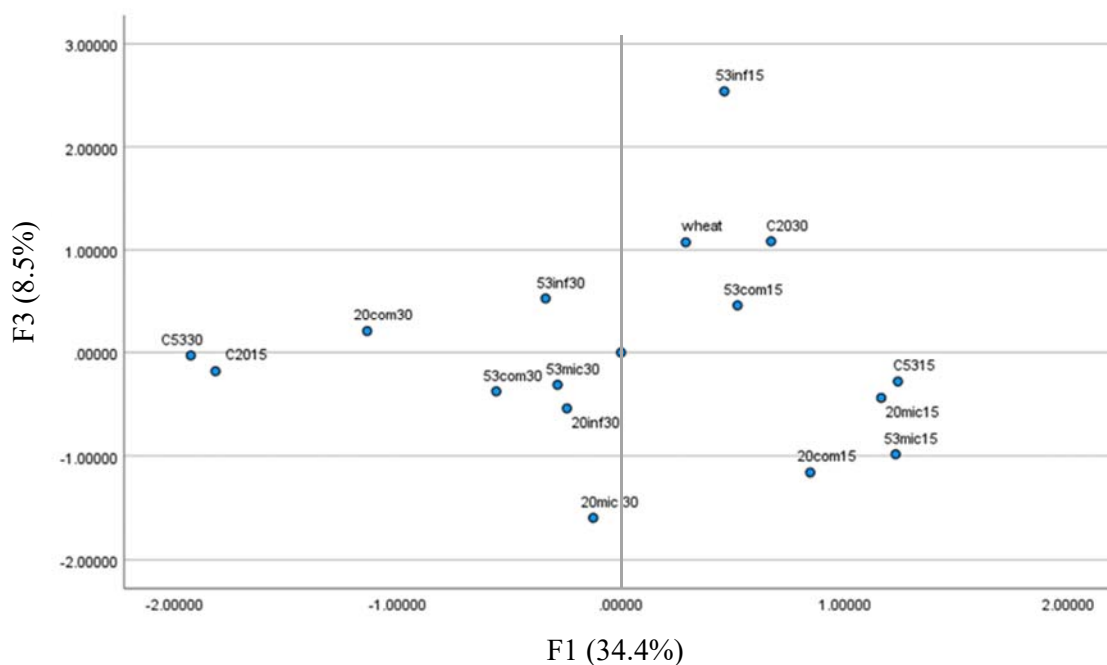


Figure S1 Principal Component Analysis showing important factors: Scores and Component Loading Plot for component 1 and 3