# MIXING PROPERTIES OF FIBRE ENRICHED WHEAT BREAD DOUGHS: A RESPONSE SURFACE METHODOLOGY STUDY

**C. M. Rosell (*), E. Santos, C. Collar**

Instituto de Agroquímica y Tecnología de Alimentos (CSIC). P.O. Box 73, 46100-Burjassot. Valencia. Spain. E-mail: crosell@iata.csic.es

**Running Title:** Effect of different fibres on wheat dough development and overmixing.

Correspondence should be addressed to:

Dr Cristina M. Rosell

Instituto de Agroquimica y Tecnologia de Alimentos (IATA)

PO Box 73, Burjasot-46100. Valencia. Spain

Tel: 34-96-390 0022

Fax: 34-96-363 6301

e-mail: crosell@iata.csic.es

## ABSTRACT

Fibre enriched baked goods have increasingly become a convenient carrier for dietary fibre. However, the detrimental effect of fibres on dough rheology and bread quality continuously encourages food technologists to look for new fibres. The effect of several fibres (Fibruline, Fibrex, Exafine and Swelite) from different sources (chicory roots, sugar beet and pea) on dough mixing properties when added singly or in combination has been investigated by applying a response surface methodology to a Draper-Lin small composite design of fibre enriched wheat dough samples. Major effects were induced on water absorption by Fibrex that led a significant increase of this parameter, accompanied by a softening effect on the dough, more noticeable when an excess of mixing was applied. Conversely, Exafine increased water absorption without affecting the consistency and stability of dough, which even improved when combined with Swelite. Fibruline showed little effect on dough mixing parameters, but showed synergistic effects with pea fibres. The overall results indicates that the use of an optimised combination of fibres in the formulation of fibre enriched dough allow improving dough functionality during processing.

**Key words:** dietary fibre, wheat dough, rheology, mixing dough properties.

## INTRODUCTION

Consumer concerns about healthy diet and convenience foods have significantly increased in the last decade. Nowadays, consumers are interested in the quality and also in the nutritive value and safety of the products they eat. Dietary fibre is considered as one of the food ingredients with a significant contribution to health. Dietary fibre (DF) is the edible portion of plants (or analogous carbohydrates) that are resistant to digestion and adsorption in the human small intestine with complete or partial fermentation in the large intestine. The term dietary fibre comprises polysaccharides, oligosaccharides and associated plant compounds [1]. The beneficial effects of the dietary fibres for human health include laxation [2], reduction of cardiovascular disease incidence [3-4] and cholesterol level, and the risk of colon cancer [5-6].

The increasing demand for healthier foods has motivated food technologists to design fibre-enriched products. From the technological view, fibres are included in food recipes, varying their uses from bulking agent to fat replacers. When added to a food matrix they can change its consistency, texture, rheological behaviour and sensory characteristics of the end product [7-9]. In baked goods, one major difficulty when dealing with fibres is their detrimental effect on consumer acceptance, due to the reduction of loaf volume, the increase of crumb hardness, the crust darkness and sometimes the effect on taste [7, 10-13]. Those drawbacks together with the healthy benefits provided by the fibre supplementation have motivated the presence in the market of numerous fibres from different sources that might solve the mentioned problems leading to enriched fibre breads with similar quality to white breads. Inulin, pea fibre, sugar beet fibre, and also fibres from cocoa, orange, coffee, sugarcane bagasse and rice straw have been lately incorporated to wheat flour in order to improve the quality of the fibre enriched breads [7-9, 13]. The effect of those fibres on dough rheology and bread quality was greatly dependent on fibre properties, and opposite effects were frequently encountered. Previous studies were mainly focused to the individual incorporation of different fibres in order to determine their suitability as dietary fibre source. However, combination of different fibres could overcome individual deficiencies counteracting their deleterious effect, and likely improving dough handling properties/machinability and gas retention ability and in consequence giving to better end products.

Rheological assessment is a good indicator of polymer molecular structure and thus of end-use performance [14]. In the case of wheat dough, rheological analysis has been successfully applied as indicator of the molecular structure of gluten and starch, and as predictors of their functionality in breadmaking performance [15-16]. One of the major breadmaking steps is mixing, where the distribution of materials, their hydration and the protein alignment take place yielding a network structure. The assessment of dough mixing properties will allow to determine its handling properties during the further processing.

The present research aims to systematically determine the effect of fibres from different sources on dough properties during mixing and overmixing when used singly or in combination at different levels, and to know the existence of synergistic and/or antagonistic effects among them by using a response surface methodology.

## MATERIALS AND METHODS

A commercial blend of wheat flour of 14.08% moisture [17], 14.22% proteins [18], 0.33% ash [19], 1.28% fat [20], 95% gluten index [21] and 405s Falling number [22]. The alveograph parameters of the wheat flour according to ICC [23] were 93 mm tenacity (P), 145mm extensibility (L) and $356x10^{-4}$J deformation energy (W). Fibres included inulin (Fibruline from Trades SA, Spain), sugar beet fibre (Fibrex from Nutritec, Spain), pea cell wall fibre (Swelite from Trades SA, Spain) and pea hull fibre (Exafine from Trades SA, Spain).

**Fibre characterization**

Moisture, protein, ash and fat were determined following the corresponding ICC methods [17-20]. Particle size distribution of the different fibres was determined by using a set of Standard sieves (from CISA, Barcelona, Spain, ISO-3310-01). Sample (100 g) was successively placed from the largest sieve to the smallest, and the weight retained on each sieve after 10min of manual shaking recorded. Physical properties included swelling, water holding capacity and water binding capacity. Swelling or the volume occupied by a known weight of fibre was evaluated by mixing 5g (± 0.1 mg) of dried fibre with 100mL distilled water and allowing it to hydrate during 16h. Water holding capacity is the amount of water retained by the fibre without being subjected to any stress. Water binding capacity or the amount of water retained by the fibre after it has been subjected to centrifugation was measured as described the AACC method [24].

**Dough mixing characteristics**

The effect of the different fibres on dough rheology during mixing was determined by a Farinograph (Brabender, Duisburg, Germany), following the ICC Method [25]. Wheat flour was replaced by combinations of fibres following a Draper-Lin small composite design for sampling (Table 3). Preliminary absorption tests were performed in the Farinograph in order to determine the working concentration range for each fibre. Design factors (quantitative independent factors) tested at three levels (-1, 0, 1), included Fibruline (from 1 to 5 g/100g flour-fibre blend basis), Fibrex (from 3 to 13g/100g flour-fibre blend basis), Exafine (from 1 to 10g/100g flour-fibre blend basis), and Swelite (from 1 to 10g/100g flour-fibre blend basis). The model resulted in 18 different combinations of fibre-enriched flour prepared in a Brabender Farinograph mixer (300g flour capacity) up to optimum dough development. The parameters determined were: water absorption or percentage of water required to yield a dough consistency of 500 Brabender Units (BU), arrival time (time to reach 500 BU consistency), dough development time (DDT, time to reach maximum consistency in minutes), stability (elapsed time at which dough consistency is kept at 500

BU), mixing tolerance index (MTI, consistency difference between height at peak and to that 5 min later, BU), departure time (time till decrease dough consistency below 500 BU), drop time (time till maximum peak consistency decreases 30 BU), dough degree of softening at 8 or 20 min (difference between maximum dough consistency and that after 8 or 20 min).

**Statistical analysis**

Multivariate analysis (stepwise regressions) and response surface plots of mixing parameters were performed using Statgraphics V.7.1 program (Bitstream, Cambridge, MN).

## RESULTS AND DISCUSSION

**Physico-chemical characteristics and functional properties of different fibres**

Physico-chemical properties of dietary fibres determine in great extent their functionality. The characteristics of the fibres used in this study, including the chemical composition, hydration properties and nutritional composition are summarized in Table 1. Fibrex showed the highest content of protein, ash and fat, thus the lowest content of carbohydrates. Exafine also contained an important amount of proteins and also minerals, which were even more abundant in Swelite. Important differences were also observed in the content of soluble and insoluble dietary fibres among the tested fibres.

Concerning the hydration properties, Fibrex exhibited the highest swelling, closely followed by Swelite, while the lowest swelling was obtained with Fibruline. When analysing the water holding capacity, the highest value (5.80) was obtained with Swelite followed by Fibrex (5.49), and again Fibruline showed the lowest value (2.06). Exactly the same trend was obtained with the water binding capacity. Similar value of water binding capacity has been previously reported for Fibrex that can bind water almost five times its weight [26-27]. The higher values of imbibed water observed in the Swelite (pea cell walls fibre) would be expected, because in general fibres composed of mainly primary cell walls retain a greater amount of water.

Hydration capacities determine in great extent the fate of dietary fibre in the digestive tract (induction of fermentation) and also account for some of their physiological effects [28]. Namely, high binding water capacity of dietary fibres has been associated to low digestibility, high volume and weight of feces and low serum triglycerides content in rat experiments [29]. Besides, fibre hydration capacities have been extensively studied due to their influence on food functionality. In breadmaking, water has a crucial role through the process, taking part in the starch gelatinization, protein denaturation, flavour and colour development [30].

Particle size distribution is of major importance determining fibre functionality. Fibres tested comprised a range of particle sizes (Table 2), being Fibruline and Fibrex the ones with the smallest particle size (openings 150μm), whereas Exafine contained the largest particles (sieve openings 200-500μm). Swelite showed and intermediate particle size (sieve openings 100-200μm). Wheat coarse bran (mean particle size 609μm) can retain significantly more water than medium (mean particle size 415μm) or fine (mean particle size 278μm) bran as measured by a centrifuge method [31]. Nevertheless, in this research, no significant effect between the hydration properties and the particle size of the fibres could be found when mean particle size ranged between 60μm to 280μm. Results indicate that a minimum particle size is required for increasing the water binding capacity.

**Effect of fibres combination on dough mixing properties**

Analytical data obtained from the Draper-Lin small composite design samples (Table 3) on dough mixing properties were fitted to multiple regression equations using added principles (design factors) as independent factors in order to estimate response surfaces of dependent mixing dough variables. In dough development and breadmaking performance, response surface curves have been successfully used for optimising ingredients [32] and processing conditions [33-34], being a useful tool when a number of processing conditions must be taken into account for defining a recipe or a process. Significant coefficients (95% confidence interval) of the added principles obtained from the stepwise regression fitting model are included in Table 4. The presence of fibres has a minor effect in some mixing parameters, such as departure time, mixing tolerance index and drop time, which are greatly dependent on the wheat protein characteristics. Mixing parameters were dependent on the presence and nature of the fibre, being particularly significant for water absorption ($R^2$=0.9770), arrival time ($R^2$=0.6698), development time ($R^2$=0.5008), dough stability ($R^2$=0.5755), and degree of dough softening at both 8 min ($R^2$=0.7586) and 20 min ($R^2$=0.8696).

Concerning water absorption, the single addition of Fibrex promoted the largest increase in water absorption (47.0%) when added at the highest level (13%, flour-fibre blend basis), having positive linear and negative quadratic significant effect. The addition of Exafine also induced a 15.1% increase of water absorption when added at the maximum level (10%, flour-fibre blend basis). The combination of both fibres only promoted an increase of the water absorption of 49.7% when added at the maximum dose (Figure 1 A), thus the addition of the pairing Fibrex-Exafine did not resulted in a great benefit regarding the water absorption. The single addition of Fibruline and Swelite did not induce changes on this parameter, but the pairing Fibrex-Swelite led to a significant increase of the water absorption (Figure 1 B). These results are in agreement with the reported effect of other different fibres [7, 10, 13, 35], although the extent of the increase varied widely with the fibre source and their composition. It has been reported [31] that the wheat bran particle size has no significant effect on dough water absorption, thus another explanation of the major water absorption in dough containing fibres could be the increasing number of hydrogen bonds formed with the hydroxyl groups presented in the fibre structure, similarly to the interaction already described with hydrocolloids [36-37]. but Addition of wheat bran into bread dough systems increased dough water absorption rate, reduced mixing time and decreased dough mixing tolerance as measured by farinograph [31].

Having in mind the hydration properties of the studied fibres, no relationship could be established in order to explain the effect of fibre addition on the water absorption. Likely, the presence of dough components, namely wheat proteins, modified the interaction of fibres with water, leading to different hydration behaviour when contained in dough formulation.

With the exception of Fibrex, the single addition of the studied fibres did not modify the arrival time, therefore the rate of dough hydration remained unchanged, and only the combination of Exafine and Swelite at the maximum level increased up to 4.3 min the arrival time (Figure 1 C). Single incorporation of Fibrex at maximum level (13%, flour-fibre blend basis) resulted in an important increase of the dough arrival time up to 8.2 min (Figure 1 D), but without having any significant effect on dough development time. Only when added in presence of Swelite, a significant synergistic effect in increasing dough development time, and thus dough strength, was observed (Figure 1 E). These results were in agreement with those reported by Wang et al [7], who did not find any significant effect on dough development time when added pea fibre or inulin to wheat dough. Conversely to the findings of Gómez et al [13], the effect of these fibres on dough development was not related to their dietary fibre composition. No relationship could be established with the particle size, although in the case of bran it has been reported that a reduction in the particle size induced a decrease in dough development time [31,38]. An increase in the mixing time has been described with the addition of wheat fibre, rye bran, oat hulls, modified celluloses and rye pentosans [10, 31, 39], which was attributed to the effect of the interaction between fibres and gluten that prevents the hydration of the proteins, affecting the aggregation and disaggregation of the high molecular weight proteins in wheat [33, 40].

The replacement of wheat flour with the single addition of the studied fibres did not modify dough stability, only a major effect on dough stability was observed with the singly addition of Fibrex that led to a decrease of 73.8% when added at the maximum dosage (Figure 2 A), and in consequence, an enhancement of the mixing tolerance index. In opposition, the pair Fibruline/Swelite, which individually did not have any single or quadratic effect, induced a noticeable increase in dough stability (Figure 2 B). Viewing previous reports, fibres addition promoted a very erratic effect on dough stability, their effect being greatly dependent on fibre composition. It has been described that the addition of 5% rye bran resulted in less stable dough [39], whereas the individual supplementation of fibres such as inulin, microcrystalline cellulose and wheat fibre produced an increase of dough stability [7]. Therefore, the effect of fibres on stability should be assessed before to their incorporation in dough formulation in order to know dough behaviour during overmixing.

Other parameters related to dough behaviour during overmixing are departure time, drop time and degree of softening at 8 and 20 minutes. Concerning the departure time, the combination of Fibruline with pea fibres (Exafine or Swelite) induced significant changes of this parameter, but meanwhile the addition with Exafine produced a decrease (Figure 2 C), the incorporation with Swelite promoted the opposite effect and of greater extent (Figure 2 D). The presence of Fibrex resulted in positive linear and negative quadratic significant effects on dough softening at 8 min and 20 min, being the maximum increase in dough softening obtained at 10.7g Fibrex/100 g flour, d.b. (maximum of the response surface plot, Figure 2 E), thus concerning this parameter higher or lower doses of Fibrex should be recommended in order to gain dough tolerance when an excess of mixing is applied. A quadratic significant effect on dough softening at 20 min was induced with the incorporation of Swelite resulting in a decrease of the degree of dough softening when overmixing, and that effect was intensified in the presence of Exafine, and it was also noticeable in dough softening at 8 min. In addition, Swelite promoted a positive quadratic dependent effect on drop time.

Scarce information has been previously reported concerning the effect of fibres on dough behaviour when an excess of mixing. Gómez et al [13] found that fibre supplemented dough were more tolerant and also showed minor consistency decay when overmixing. Nevertheless, Laurikainen et al [39] found that the addition of rye bran had little effect on dough softening. Therefore, previous results and results obtained in the present study indicate that the diverse composition and nature of the fibres do not allow to make general assessments about the effect of the fibres on dough during an excess of mixing, and the same applies to the rest of the dough mixing characteristics.

Overall effect on dough mixing characteristics shows that Fibrex is the fibre that exerted the greatest significant effect on dough mixing parameters when added alone, and moreover synergistic and/or antagonistic effects are observed in the presence of pea derived fibres.

**Relationships within dough mixing parameters in enriched fibre wheat dough**

Multivariate data handling provides information on the significant correlations within the mixing parameters. In this study, a range of correlation coefficients within the mixing parameters was obtained by using Pearson correlation analysis (Table 5). Dough water absorption showed positive correlation with arrival and development time, mixing tolerance index and degree of softening at 8 and 20 minutes; whereas it was negatively correlated with dough stability and departure time, and therefore with the parameters related to overmixing. This correlation was confirmed by the fact that samples with higher water absorption were those containing Fibrex, which also showed lower stability to an excess of mixing. Dough stability showed positive relationship with the departure time and negative correlation with the parameters related to dough consistency during overmixing, such as mixing tolerance index, and degree of dough softening at 8 and 20 minutes. Parameters that defined dough behaviour during an excess of mixing showed major correlations within them.

To conclude, parameters that define dough mixing behaviour were significantly affected by fibre supplementation, and the extent of the effect was greatly dependent on the physico-chemical and functional properties of the fibres. The combination of fibres with different functional properties could be advisable for overcoming the detrimental effect of fibres on the performance of fibre enriched doughs.

**REFERENCES**


1. AACC (2001) Cereal Food World 46: 112-126
2. Rigaud D, Paycha F, Meulemans A, Merrouche M, Mignon M (1998) Eur J Clin Nutr 52: 239-245
3. Mozaffarian D, Kumanyika SK, Lemaitre RN, Olson JL, Burke GL, Siscovick DS (2003) J Am Med Assoc 289: 1659-1666
4. Jensen MK, Koh-Banerjee P, Hu FB, Franz M, Sampson L, Gronbaek M, Rimm EB (2004) Am J Clin Nutr 80: 1492-1499
5. Whitehead RH (1986) Gut 27: 1457-1463
6. Anderson JW (1991) Am J Clin Nutr 54: 678-683
7. Wang J, Rosell CM, Benedito C (2002) Food Chem 79: 221-226
8. Sangnark A, Noomhorm A (2004) Lebensm. Wiss.u-Technol 37: 697-704
9. Sangnark A, Noomhorm A (2004) Food Res Int 37: 66-74
10. Pomeranz Y, Shogren M, Finney KF, Bechtel DB (1977) Cereal Chem 54: 25-41
11. Knuckles BE, Hudson CA, Chiu MM, Sayre RN (1997) Cereal Foods World 42(2): 94-100
12. Lai CS, Hoseney RC, Davis AB (1989) Cereal Chem 66: 217-219
13. Gómez M, Ronda F, Blanco CA, Caballero PA, Apesteguía A (2003) Eur Food Res Technol 216: 51-56
14. Marin G, Montfort JP (1996) Rheology for polymer melt processing. Elsevier, Amsterdam.

15. Collar C, Bollaín C (2004) Eur Food Res Technol 218: 139-146
16. Collar C, Bollaín C (2005) Eur Food Res Technol 220: 372-379
17. ICC-Standard No 110/1 Approved 1960, Revised 1976
18. ICC-Standard No 105/2 Approved 1980, revised 1994
19. ICC-Standard No 104/1 Approved 1960, revised 1990
20. ICC-Standard No 136 Approved 1984
21. ICC-Standard No 155 Approved 1994
22. ICC-Standard No 107/1 Approved 1968, revised 1995
23. ICC-Standard No 121 Approved 1972, revised 1992
24. AACC (1999) Method 56-30 Approved Methods of the American Association of Cereal Chemists. The Association, St Paul, MN
25. ICC-Standard No 115/1 Approved 1972, revised 1992
26. Dreher ML (1987) Handbook of dietary fibre: an applied approach. Marcel Dekker, New York.
27. Abdul-Hamid A, Luan YS (2000) Food Chem 68: 15-19
28. Guillon F, Champ M (2000) Food Res Technol 33: 233-245
29. Sosulski FW, Cadden AM (1982) J Food Sci 47: 1472-1477
30. Pomeranz Y (1985) Functional properties of food components. Academic Press, Inc, New York
31. Zhang D, Moore WR (1997) J Sci Food Agric 74: 490-496
32. Sidhu JS, al-Hooti SN, Al-Saqer JM (1999) Food Chem 67: 365-371
33. Kenny S, Grau H, Arendt EK (2001) Eur Food Res Technol 213: 323-328
34. Magnus EM, Brathen E, Sahlstrom S, Mosleth Faergestad E, Ellekjaer MR (1997) J Cereal Sci 25: 289-231
35. Park H, Seib PA, Chung OK (1997) Cereal Chem 74: 207-211
36. Collar C, Andreu P, Martínez JC, Armero E (1999) Food Hyd 13: 467-475
37. Chen H, Rubenthaler GL, Schanus EG (1988) J Food Sci 53: 304-305
38. Krishnan PB, Chang KC, Brown G (1987) Cereal Chem 64: 55-58

39. Laurikainen T, Harkonen H, Autio K, Poutanen K (1998) J Sci Food Agric 76: 239-249
40. Michniewicz J, Biliaderis CG, Bushuk W (1991) Cereal Chem 68: 252-258

## FIGURE CAPTIONS

**Figure 1.** Response surface plots of single and interactive effects of different fibres on dough mixing characteristics. The amount of fibres is expressed as grams of fibre per 100g flour-fibre blend basis A-B: water absorption; C-D: arrival time; E: development time.

**Figure 2.** Response surface plots of single and interactive effects of different fibres on dough mixing parameters when an excess of mixing. The amount of fibres is expressed as grams of fibre per 100g flour-fibre blend basis.

**Table 1.** Proximate chemical analysis and hydration properties of the commercial fibres used in this study.

| | | Fibruline | Fibrex | Exafine | Swelite |
|---|---|---|---|---|---|
| Chemical composition (%)[a] | Moisture content | 6.39 | 9.18 | 10.35 | 12.44 |
| | Protein | 0.04 | 8.06 | 3.25 | 0.62 |
| | Ash | 0.01 | 3.84 | 1.04 | 1.74 |
| | Fat | 0.04 | 0.46 | 0.09 | 0.20 |
| | Total Carbohydrates [b] | 93.5 | 78.46 | 85.3 | 85.0 |
| Hydration properties | Swelling (ml/g) | 2.32 | 6.60 | 4.60 | 6.40 |
| | WHC (g water/g solid) | 2.06 | 5.49 | 3.79 | 5.80 |
| | WBC (g water/g solid) | 0.12 | 4.32 | 3.39 | 4.68 |
| Nutritional composition[c] | Total dietary fibre | 92.1 | 73.0 | 80.0 | 35.0 |
| | Insoluble dietary fibre | - | 49.0 | 78.4 | n.a. |
| | Soluble dietary fibre | 92.1 | 24.0 | 1.6 | n.a. |

[a] Dry basis
[b] Calculated by difference
[c] Data provided by the supplier (%)
WHC: water holding capacity; WBC: water binding capacity; n.a.: not available.

**Table 2.** Particle size distribution of fibres from different sources.

| | g / 100 g sample over sieve opening of | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 500 μm | 300 μm | 200 μm | 150 μm | 100 μm | 75 μm | 50 μm | 25 μm | Through 25 |
| Fibruline | - | - | - | 1.74 | 23.01 | 20.03 | 29.34 | 24.65 | 1.22 |
| Fibrex | - | - | 0.22 | 2.33 | 34.99 | 13.91 | 18.30 | 29.12 | 1.13 |
| Exafine | 16.13 | 49.78 | 15.96 | 7.47 | 3.93 | 1.62 | 1.09 | 1.25 | 2.76 |
| Swelite | 8.12 | 13.61 | 12.83 | 24.53 | 18.27 | 5.14 | 5.53 | 5.58 | 6.39 |

**Table 3.** Draper-Lin small composite design for sampling. The design factors were Fibruline (FN), Fibrex (FX), Exafine (EX), Swelite (TX).

| Run | FN | FX | EX | TX |
|---|---|---|---|---|
| 1 | 0 (3) | 0 (8) | 0 (5.5) | 0 (5.5) |
| 2 | 0 (3) | 1 (13) | 0 (5.5) | 0 (5.5) |
| 3 | -1 (1) | -1 (3) | -1 (1) | -1 (1) |
| 4 | 1 (5) | -1 (3) | 1 (10) | 1 (10) |
| 5 | 0 (3) | 0 (8) | 1 (10) | 0 (5.5) |
| 6 | 0 (3) | 0 (8) | 0 (5.5) | 1 (10) |
| 7 | 0 (3) | 0 (8) | 0 (5.5) | -1 (1) |
| 8 | 1 (5) | 0 (8) | 0 (5.5) | 0 (5.5) |
| 9 | -1 (1) | 0 (8) | 0 (5.5) | 0 (5.5) |
| 10 | 1 (5) | -1 (3) | -1 (1) | 1 (10) |
| 11 | 0 (3) | -1 (3) | 0 (5.5) | 0 (5.5) |
| 12 | -1 (1) | 1 (13) | 1 (10) | 1 (10) |
| 13 | 1 (5) | 1 (13) | 1 (10) | -1 (1) |
| 14 | -1 (1) | -1 (3) | 1 (10) | -1 (1) |
| 15 | 0 (3) | 0 (8) | -1 (1) | 0 (5.5) |
| 16 | 1 (5) | 1 (13) | -1 (1) | -1 (1) |
| 17 | -1 (1) | 1 (13) | -1 (1) | 1 (10) |
| 18 | 0 (3) | 0 (8) | 0 (5.5) | 0 (5.5) |

The numbers in parenthesis indicate the amount of fibres in grams per 100g flour-fibre blend basis.

**Table 4**. Significant coefficients (95% confidence interval) of the design factors (independent variables) of the stepwise regression fitting model for the mixing characteristics. The independent variables were Fibruline (FN), Fibrex (FX), Exafine (EX) and Swelite (TX).

| Factor | Farinograph parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | WA, | Arrival time, | Departure time, | Development time, | Stability, | MTI, | Drop time, | Degree of softening, 20 ' | Degree of softening, 8 ' |
| | % | min | min | Min | min | BU | min | BU | BU |
| CONSTANT | 59.039 | 1.208 | 16.866 | 8.391 | 15.663 | 13.422 | 12.629 | 11.847 | -4.843 |
| FN | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| FX | 2.756 | 0.540 | ns | ns | -0.889 | 3.600 | ns | 11.011 | 11.000 |
| EX | 0.889 | ns | ns | ns | ns | ns | ns | ns | ns |
| TX | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| $FN^2$ | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| $FX^2$ | -0.048 | ns | ns | ns | ns | ns | ns | -0.513 | -0.450 |
| $EX^2$ | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| $TX^2$ | ns | ns | ns | ns | ns | ns | 0.052 | -0.195 | ns |
| FN*FX | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| FN*EX | ns | ns | -0.154 | ns | ns | ns | ns | ns | ns |
| FN*TX | ns | ns | 0.261 | ns | 0.195 | ns | ns | ns | ns |
| FX*EX | -0.056 | ns | ns | ns | ns | ns | ns | ns | ns |
| FX*TX | 0.058 | ns | ns | 0.037 | ns | ns | ns | ns | ns |
| EX*TX | ns | 0.031 | ns | ns | ns | ns | ns | -0.172 | -0.268 |
| R-SQ | 0.9770 | 0.6698 | 0.4480 | 0.5008 | 0.5755 | 0.3839 | 0.3508 | 0.8696 | 0.7586 |

ns: no significant effect at level < 5 %.
R-SQ: adjusted square coefficient of the fitting model.
WA: water absorption; MTI: mixing tolerance index.

**Table 5.** Coefficient of significant correlations (P<0.05) within dough mixing parameters obtained from the Farinograph.

| | Farinograph parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Arrival time, min | Development time, min | Stability, min | Departure time, min | MTI, BU | Degree of softening, 20 ' BU | Drop time, min | Degree of softening, 8 ' BU |
| Water absorption (%) | 0.8144 | 0.6619 | -0.7064 | -0.5899 | 0.6651 | 0.4640 | | 0.6287 |
| Arrival time (min) | | 0.7947 | -0.7168 | -0.5168 | | | | |
| Development time (min) | | | | | | | 0.6215 | |
| Stability (min) | | | | 0.9454 | -0.5551 | -0.7159 | | -0.6629 |
| Departure time (min) | | | | | -0.6409 | -0.7971 | 0.5112 | -0.6612 |
| MTI (BU) | | | | | | 0.7676 | -0.6572 | 0.7710 |
| Degree of softening 20min (BU) | | | | | | | -0.7621 | 0.9051 |
| Drop time (min) | | | | | | | | -0.5369 |

Figure 1.

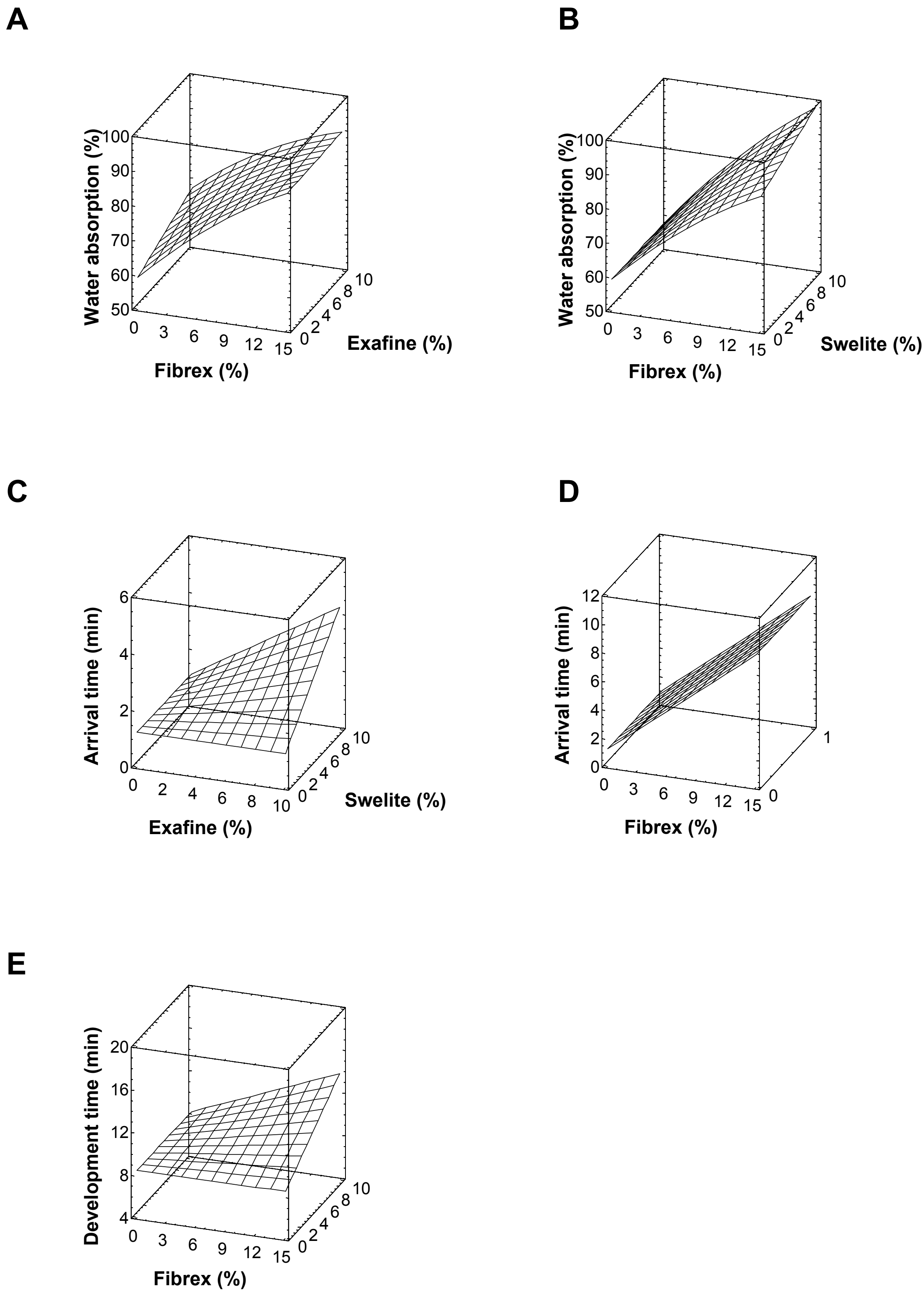
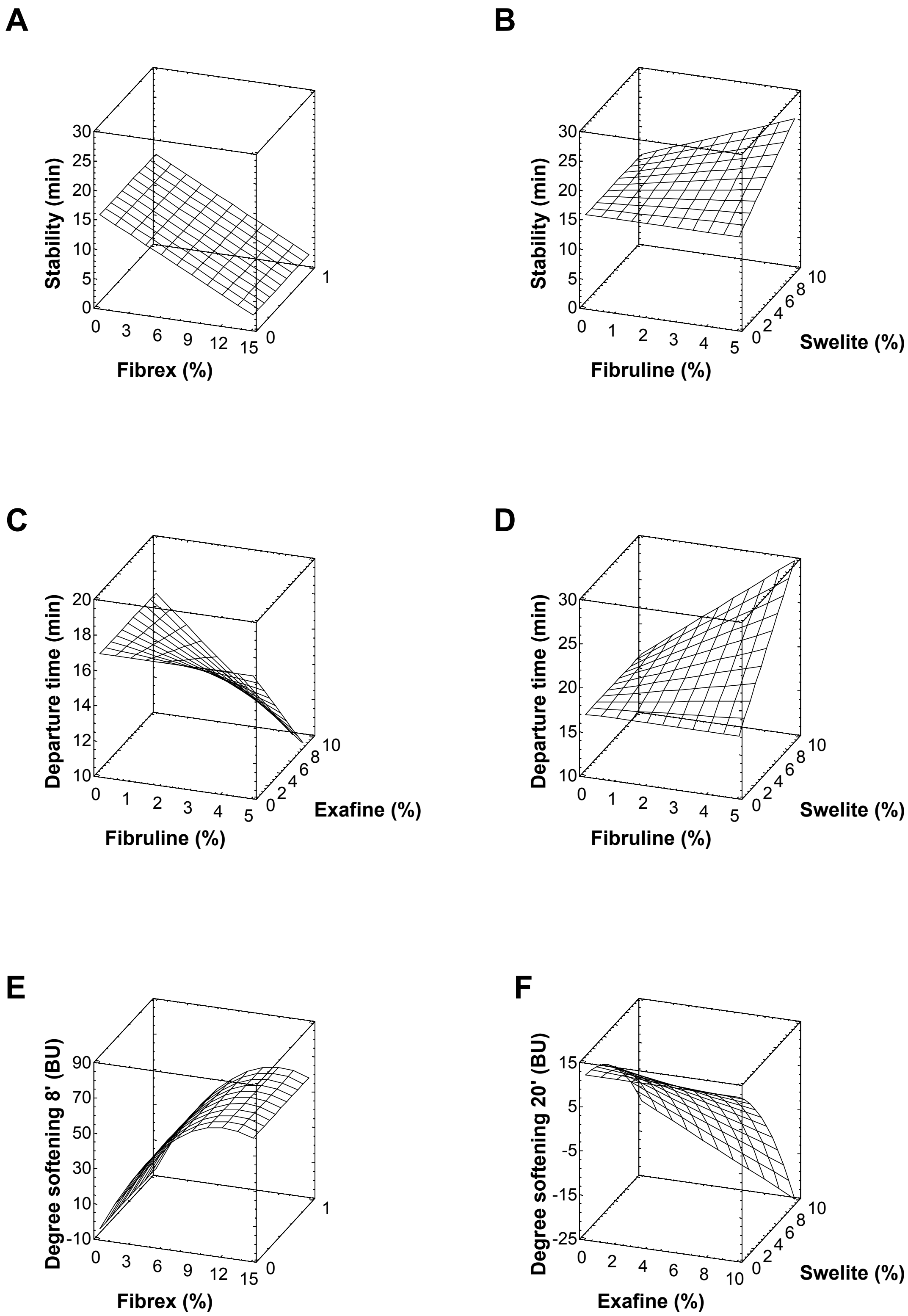

A
Water absorption (%)
100
90
80
70
60
50
0 3 6 9 12 15
Fibrex (%)
0 2 4 6 8 10
Exafine (%)
B
Water absorption (%)
100
90
80
70
60
50
0 3 6 9 12 15
Fibrex (%)
0 2 4 6 8 10
Swelite (%)
C
Arrival time (min)
6
4
2
0
0 2 4 6 8 10
Exafine (%)
0 2 4 6 8 10
Swelite (%)
D
Arrival time (min)
12
10
8
6
4
2
0
0 3 6 9 12 15
Fibrex (%)
0
1
E
Development time (min)
20
16
12
8
4
0 3 6 9 12 15
Fibrex (%)
0 2 4 6 8 10

Figure 2.


A
Stability (min)
0
5
10
15
20
25
30
Fibrex (%)
0 3 6 9 12 15
0
1
B
Stability (min)
0
5
10
15
20
25
30
Fibruline (%)
0 1 2 3 4 5
Swelite (%)
0 2 4 6 8 10
C
Departure time (min)
10
12
14
16
18
20
Fibruline (%)
0 1 2 3 4 5
Exafine (%)
0 2 4 6 8 10
D
Departure time (min)
10
15
20
25
30
Fibruline (%)
0 1 2 3 4 5
Swelite (%)
0 2 4 6 8 10
E
Degree softening 8' (BU)
-10
10
30
50
70
90
Fibrex (%)
0 3 6 9 12 15
0
1
F
Degree softening 20' (BU)
-25
-15
-5
5
15
Exafine (%)
0 2 4 6 8 10
Swelite (%)
0 2 4 6 8 10