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THEORETICAL PREREQUISITES FOR ADAPTING TRADITIONAL BAKERY TECHNOLOGY TO THERAPEUTIC AND DIETARY PRODUCTION

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Abstract:
The traditional bread-making scheme evolved for wheat dough whose structure is built on a gluten framework, and it is not optimal once functional ingredients are introduced and thermolabile components must be preserved. This paper sets out the theoretical prerequisites for adapting the traditional technological scheme to the requirements of therapeutic and dietary bakery production. The scheme is treated as a controllable system of stages in which the functional load creates specific deviations from the standard regime that call for compensating technological solutions, subject to the principle of minimal technological intervention. Critical adaptation points are identified at raw-material preparation (pre-treatment of functional ingredients), dough mixing (choice of the dough-making method and compensation of gluten weakening), fermentation (sourdough and acidity control), baking (gentle, zone-differentiated regimes for thermolabile components) and the final stages (post-baking addition of probiotics and barrier packaging). Gluten-free production is considered as a special, fundamental case in which a system of hydrocolloids replaces the structural functions of gluten. The safety and guaranteed functionality of the products are addressed through HACCP-based quality management. The proposed adaptation closes the theoretical loop between recipe design and the practical manufacturability of functional bakery products.

Keywords: Functional Bakery Products, Therapeutic and Dietary Nutrition, Technological Scheme Adaptation, Sourdough, Dough-Making Method, Gluten-Free Bread, Hydrocolloids, Mineral Bioavailability, Glycemic Index, HACCP

Introduction

The traditional technological scheme of bread-making developed historically for wheat dough, the structure formation of which is based on a gluten framework. The introduction of functional ingredients and the need to preserve thermolabile components disturb the conditions for which this scheme is optimal and create the need for its purposeful adaptation. The theoretical prerequisite for adaptation is the view of the technological scheme as a controllable system of stages, at each of which the functional load creates specific deviations from the standard regime that require compensating technological solutions [1]. The adaptation is governed by the principle of minimal technological intervention: changes are introduced only to the extent necessary to achieve the intended functional orientation while preserving acceptable consumer properties and economic efficiency.

The aim of this work is to substantiate the theoretical prerequisites for the transition from the traditional to an adapted technological scheme, to identify the critical points at which therapeutic-dietary production differs fundamentally from the classical process, and to systematize the directions of adaptation by stage of the technological cycle.

Materials and Methods

The object of the study was the technological scheme of bakery production considered as a multistage controllable system "raw materials – formulation – process – storage". The traditional scheme (raw-material preparation and dosing → dough mixing → fermentation → dividing and forming → proofing → baking → cooling, finishing and packaging) was analyzed stage by stage in order to identify the critical points at which the production of therapeutic-dietary products deviates from the classical process. For each stage, the specific problem created by the functional load, the corresponding adaptation solution and its expected effect were determined; the results were systematized in the form of stage-by-stage adaptation tables and a generalized adapted scheme. The substantiation of the baking-regime adaptation relies on the kinetic regularities of thermal degradation of thermolabile components (a first-order reaction with an Arrhenius temperature dependence) established previously. The quantitative estimates of the effect of adaptation shown below are illustrative and were obtained from generalized literature data.

Results and Discussion

Traditional scheme and critical adaptation points. The analysis of the traditional scheme makes it possible to identify the critical points at which the production of therapeutic-dietary products differs fundamentally from the classical one. A generalized adapted scheme with the adaptation points marked is shown in Figure 1. The key adaptation points are: the raw-material preparation stage (introduction of preliminary treatment of functional ingredients), the mixing stage (choice of the dough-making method and compensation of gluten weakening), the fermentation stage (use of sourdoughs and regulation of acidity), the baking stage (gentle regimes for thermolabile components) and the final stages (post-baking addition of probiotics and the use of barrier packaging).

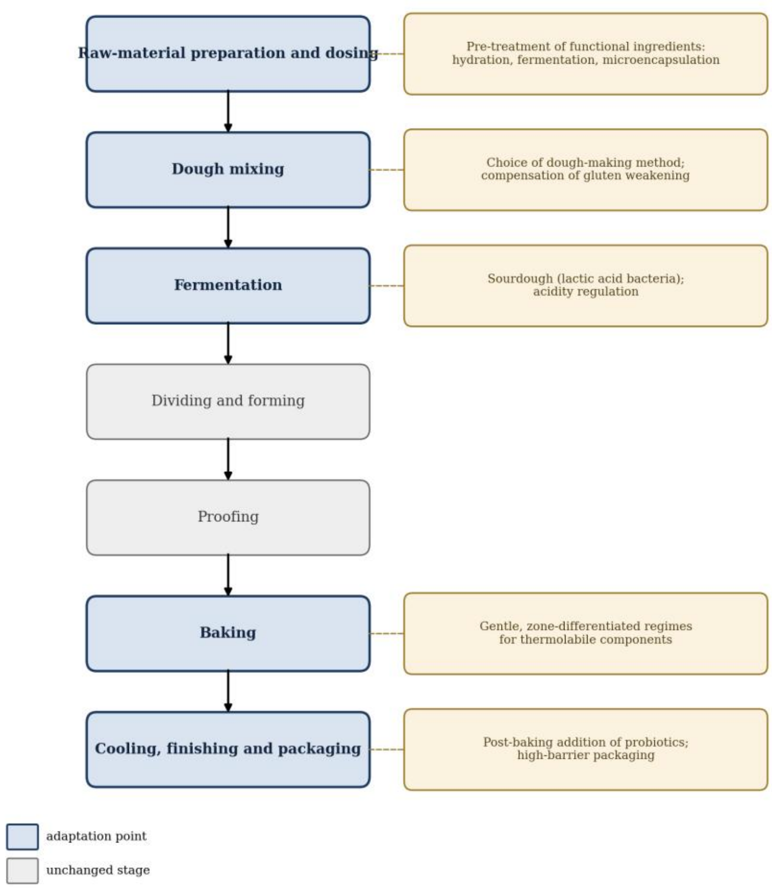

Figure 1. Adapted technological scheme for the production of bakery products of therapeutic and dietary purpose, with adaptation points marked

Adaptation of raw-material preparation and the choice of dough-making method. The first prerequisite for adaptation is the introduction of a stage of preliminary preparation of the functional ingredients. Hydration of dietary fibres and plant proteins before mixing reduces their competition with gluten for water and improves the dough structure; fermentation of the raw material on sourdoughs increases the bioavailability of minerals through the hydrolysis of phytates and lowers the glycemic index of the product; and microencapsulation of probiotics protects the cells from subsequent thermal action [2]. Sourdough fermentation lowers the dough pH and activates phytase, so that the phytate content can be reduced substantially — by up to about 70 % or more depending on the fermentation conditions — with a corresponding increase in the bioaccessibility of iron, zinc, magnesium and calcium [3], [4]. The same fermentation, through the formation of organic acids and interactions between starch and gluten, lowers the glycemic index of the product to roughly 53–55, compared with about 70–75 for ordinary white bread [5]. The valuable biotechnological properties of sourdough lactic acid bacteria — antimicrobial activity, proteolysis and acidification — are confirmed by modern reviews. The second prerequisite is a justified choice of the dough-making method depending on the magnitude of the functional load: at a low degree of enrichment the straight-dough method is retained; at a medium degree the sponge-and-dough method is preferable, providing better gluten development; and where the aim is to increase bioavailability, lower the glycemic index and extend shelf life, a transition to sourdough technology is justified. Recommendations for the choice of the dough-making method are systematized in Table 1.

Table 1. Choice of the dough-making method depending on the functional load of the formulation

Functional load	Recommended method	Technological rationale	Target groups
Low (premix enrichment, ≤ 5 %)	Straight dough	Minimal change in rheology; simplicity	**Mass social products**
Medium (plant protein, dietary fibre 5–15 %)	Sponge-and-dough	Better gluten development; compensation of weakening	**Children, adults, the elderly**
High (bioavailability, ↓ GI, shelf life)	Sourdough (lactic acid bacteria)	Reduced phytate and GI; longer shelf life without preservatives	**Type 2 diabetes, cardiovascular disease, the elderly**
Gluten-free production	Special scheme with hydrocolloids	Structure formation without gluten	**Coeliac disease, gluten intolerance**

Adaptation of fermentation, baking and final stages. Adaptation of the fermentation regime is associated with the regulation of titratable acidity, which determines both the bioavailability of nutrients and the microbiological stability of the product. The most essential is the adaptation of the baking regime: the kinetic regularities of thermal degradation established earlier (a first-order reaction with an Arrhenius dependence) justify the use of gentle and zone-differentiated baking regimes that minimize excessive thermal action on thermolabile vitamins and vegetative probiotic cells while maintaining adequate baking of the crumb [6]. The final stages are adapted by introducing probiotic cultures after baking (in fillings, creams or surface coatings) and by using packaging with high barrier properties that limits oxidative deterioration and moisture exchange [7]. The directions of adaptation by stage of the technological process are systematized in Table 2, and the quantitative effect of the adaptation of the scheme is shown in Figure 2.

Table 2. Directions of adaptation of the technological scheme by process stage

Process stage	Specific problem	Adaptation solution	Effect
Raw-material preparation	Competition of enrichers for water; death of probiotics	Hydration of fibre and proteins; fermentation; microencapsulation	**Improved rheology; protection of cultures**

Dough mixing	Weakening of the gluten framework	Sponge-and-dough method; oxidative and enzyme improvers	**Restored gas retention**
Fermentation / sourdough	Low bioavailability; high glycemic index	Sourdoughs on lactic acid bacteria; acidity regulation	**↑ bioavailability, ↓ GI, ↑ shelf life**
Baking	Thermal degradation of labile components	Gentle and zonal regimes; protected forms	**Retention of vitamins and probiotics**
Finishing and packaging	Oxidation; continuing loss of cultures	Post-baking addition of probiotics; barrier packaging	**Extended functionality during storage**

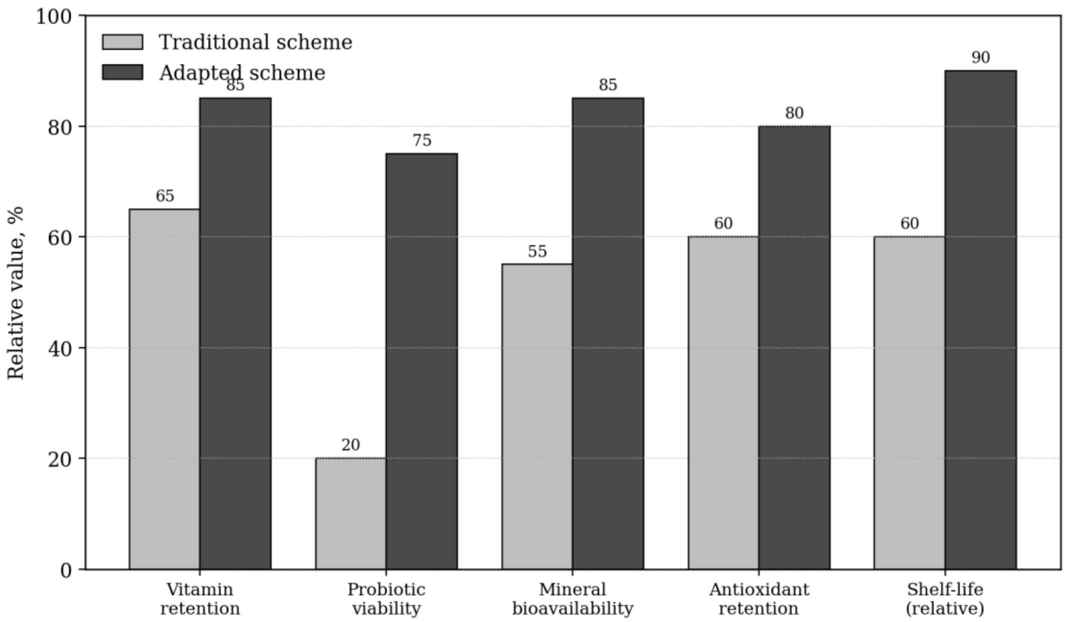

Figure 2. Effect of the adaptation of the technological scheme on the quality and retention of the functional components of an enriched product (model calculation)

Gluten-free production as a special case of adaptation. The production of gluten-free products for persons with coeliac disease and gluten intolerance represents not a partial but a fundamental adaptation of the technological scheme, since in the absence of gluten the traditional formation of a gas-holding framework is impossible. The theoretical basis of structure formation in this case is the replacement of the functions of gluten by a system of hydrocolloids and starches: hydroxypropylmethylcellulose (HPMC), xanthan gum and psyllium increase the viscosity of the liquid phase, stabilize the gas bubbles and form a polymer network that retains carbon dioxide during proofing and baking [8]. Modern studies confirm that HPMC provides the highest specific volume and crumb softness, and that its combination with xanthan or psyllium gives a synergistic effect, the level of hydration and the viscosity of the hydrocolloid being decisive. The comparative profile of the technological properties of traditional, enriched (adapted) and gluten-free dough (Figure 3) clearly demonstrates the shift of properties: gluten-free dough is characterized by reduced gas-holding capacity and elasticity, compensated by increased water retention due to the hydrocolloids. An additional prerequisite for the adaptation of gluten-free production is the organization of separate technological flows and zones that exclude cross-contamination with gluten.[9][10]

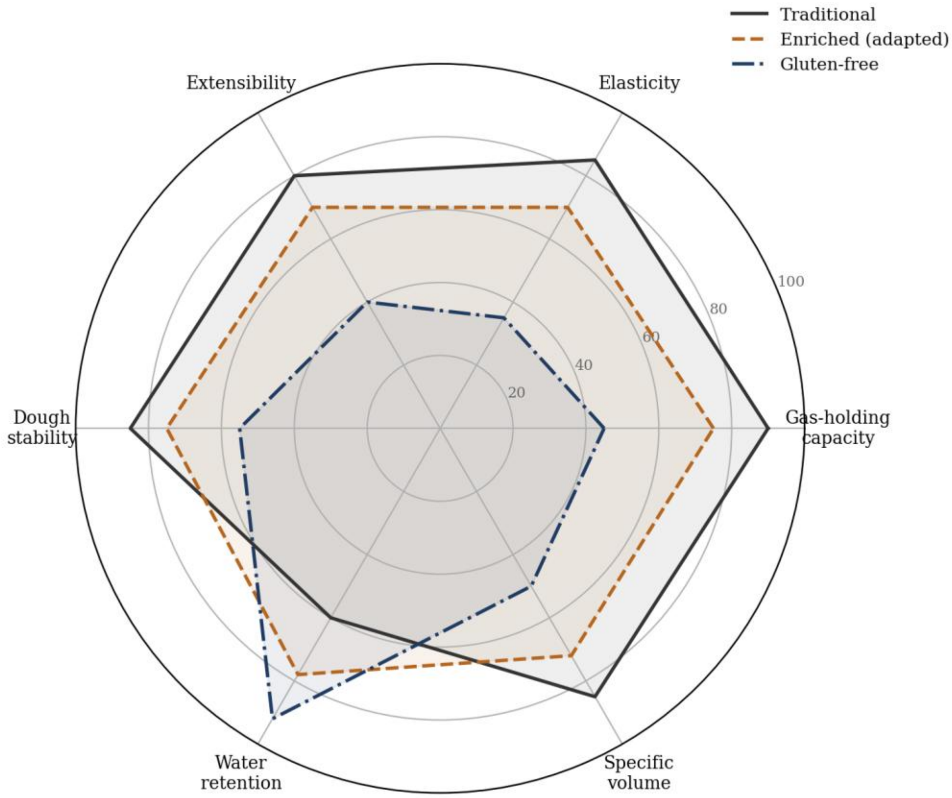

Figure 3. Comparative profile of the technological properties of the dough of traditional, enriched and gluten-free bakery products

Ensuring safety and guaranteed functional properties. An essential theoretical prerequisite for adaptation is the tightening of requirements for safety management and the guarantee of functional properties.[11][12] Therapeutic-dietary production is characterized by specific critical control points absent from ordinary production: control of allergens (primarily gluten in gluten-free products), assurance of microbiological safety and of the specified number of viable cells in probiotic products, and guaranteed achievement of the normalized level of enrichment taking into account technological losses. This necessitates building a quality-management system on the principles of HACCP and the requirements of food-safety regulation [13], [14], and setting the enrichment overage so that the declared functional level is reached in the finished product despite processing losses [15]. Thus, the set of prerequisites considered forms the theoretical basis for the transition from a traditional to an adapted technological scheme in which each stage is modified in accordance with the functional orientation of the product and its safety requirements.

Conclusion

The traditional bakery scheme, optimal for conventional wheat bread, requires purposeful adaptation once the product acquires a functional, therapeutic-dietary orientation. The adaptation is most rationally carried out on the basis of the principle of minimal technological intervention, with modification concentrated at the critical points of the process: preliminary treatment of functional ingredients, the choice of the dough-making method, sourdough fermentation and acidity control, gentle baking regimes, post-baking introduction of probiotics and barrier packaging. Gluten-free production constitutes a fundamental case of adaptation in which a system of hydrocolloids replaces the structural functions of gluten. Combined with HACCP-based safety management and a justified enrichment overage, the substantiated adaptation of technological schemes ensures the practical realizability of recipes designed and optimized at earlier stages and closes the theoretical loop between formulation and manufacturable functional bakery products.

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