ABSTRACT

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Area of research: Food Engineering & Technology

Title of thesis: Development, evaluation and in-vitro digestibility study of bakery products prepared from blend of germinated cereal grains and pulses.

Scope of research: Multi grain (cereal and legume fortified) cookies.

Cereals and legumes are the important and primary source of energy in human diet for long time. They are the important source of protein in daily diet for millions of people in the world. However contribution of nutrition to the consumer is limited due to poor digestibility and anti-nutritional factors etc. But the practices like Soaking, Germination, Fermentation and Cooking before consumption or product formation affect anti-nutritional factors significantly, which in turn increase their digestibility and biological value. Besides that many studies reveal the use of these treatments to increase nutritional availability and enhancement in biological value of product. Of all these treatments soaking, germination and cooking decrease anti-nutritional factors significantly and increase the bioavailability of nutrients, whereas germination is considered the most effective and simpler method to improve the nutritional aspect of cereal and legumes.

Consumer food industry mainly consists of ready-to-eat and ready-to-cook products, salted snacks, chips, pasta products, cocoa based products, bakery products, biscuits, soft drinks, etc. There are around 60,000 bakeries, several pasta food units and 20,000 traditional food units in
India. The bakery industry is among the few processed food segments whose production has been increasing consistently in the country in the last few years. Products of bakery include bread, biscuits, pastries, cakes, buns, rusk etc. This activity is mostly concentrated in the unorganized sector. Bread and biscuits constitute the largest segment of consumer foods with an annual production of around 4.00 million tons.

**Objectives**

Research was carried out under following objectives:

- Optimization and study the germination of selected cereals and pulses and its effect on physico-chemical characteristics.
- Development of Bakery products from composite flour of germinated cereals, pulses and millets, and their evaluation.
- Characterization of developed bakery products.
- *In-vitro* digestibility studies, amino acid profile and nutritional status of developed bakery products.

**Overview of Chapters**

On the basis of research objectives, thesis is divided into various Chapters.

1. Chapter-I, comprises the general introduction about the elements of research
2. Chapter-II, gives the general review of literature
3. Chapter-III to VII, covers the different aspects of objective-I, like physico-chemical properties, functional properties, anti-nutritional factors and amino acid profiling of selected raw and germinated seed grains
4. Chapter-VIII, covers objective-II in detail, which deals with the optimization of product formulations
5. Chapter-IX covers objective-III in detail, which is about the characterization of developed optimized product.

6. Chapter-X covers objective-IV in detail, which deals with the in vitro digestibility studies, nutritional status and partial shelf life study of product.

7. Chapter-XI comprises of references.

8. Chapter-XII concludes the research in form of summary and conclusions.

In the chapter-I general introduction of research is given. It covers the explanation of raw material like cereal and legumes, used in present research. Cereal (wheat, triticale, brown rice, pearl millet) and legumes (chickpea and kidney bean) were used for research in form of seed grains. The introduction part mainly covers the general description of seeds, their physiology and their importance as food grains. General description of processing like soaking, germination, fermentation and cooking was also discussed briefly at the end of Chapter-I.

Chapter-II starts with the general description of core element of research i.e. germination. It describes the process of germination and its traditional approach to improve the nutritional characteristics. Unknowingly, germination has been employed in the preparation of various food item across globe from long time. In the last decade effect of germination on the nutritional characteristic of food grains was topic of interest for various researchers. Further in this chapter effect of germination on various nutritional parameters like proteins, carbohydrates, fats, fibers, vitamins, trace elements, anti-nutritional factors, amino acid composition and in-vitro digestibility has been discussed.

Chapter-III deals with the soaking kinetics and optimization of germination process for selected seed grains under different selected chemical stresses. Soaking kinetics was studied under various parameters like moisture absorption tendency, moisture absorption rate and Peleg’s
constant. Values of Peleg’s rate constant where found lower were in NaOH solution for wheat, triticale (2.66×10^{-2}), (3.29×10^{-2}), in distilled water for paddy, pearl millet, kidney bean (4.49×10^{2}), (1.02×10^{-2}), (1.86×10^{-2}) in magnesium chloride for 3.9×10^{-3} for chickpea. Lower values of Peleg’s constant depicts higher initial moisture absorption rate. Effect of soaking solutions on the dimensional properties has also been discussed in this chapter. Dimensional properties includes basic measurements across each axis (Length, width and thickness), based on which sphericity, aspect ratio, volume and surface area were calculated. Germination of seed grains soaked under different chemical stresses was analyzed to optimize the soaking medium. Germination was optimized on the basis of germination parameters like germination percentage, vigor value, mean germination time, mean germination rate and coefficient of variation of germination time. Mean germination time and percentage of distilled water soaked grains were found appropriate and values for mean germination time in distilled water soaked grains varied as 2.19 days for wheat, 2.26 days for triticale, 2.85 days for paddy, 2.53 days and 3.28 days, whereas for pearl millet, the values were optimum in NaOH and MgCl\(_2\), which were reported as 2.99 and 2.98 days. After germination optimization, the seed grains germinated under optimized conditions were further subjected to analysis as per the objective-I. Distilled water was found optimum soaking medium for all the selected grains except pearl millet, where NaOH (0.1%) was found optimum for high germination index.

Chapter-IV deals with the effect of germination on physico-chemical properties of selected seed grains. In this chapter compositional characteristics along with trace elements and morphological properties were studied. The compositional characteristics included protein, ash, carbohydrate, starch, amylose, amylopectin, sugars lipid, fiber and folic acid content of raw and germinated seed grains (selected cereal and legumes). Protein content was found higher in legumes and further improved with germination. Chickpea protein content varied from 19.5 to 21.63 g/100g
sample, whereas protein content of kidney bean varied from 20.77 to 23.36 g/100g sample. Trace element analysis of both raw and germinated seed grains included calcium, iron, magnesium, phosphorus, sodium and zinc. Iron content of wheat varied significantly (p≤0.05) and was reported higher in germinated sample (4.71±0.09). Scanning electron micrographs of flour samples was analyzed under morphological characteristic. Germination affects the physicochemical properties of seed grains. Breakdown of complex molecules into simpler molecules takes place as a result of germination. SEM micrographs also indicated the effect of germination at molecular level. Protein content increased in all cases and carbohydrate content decreased. Trace elements also varied in some cases. Folic acid content increased as a result of germination in all cases. SEM micrographs were observed with distorted starch structures and porous surfaces in germinated flours.

Chapter-V deals with the effect of germination on the functional properties of flour prepared from different selected seed grains. Functional properties are important to observe the effect of processing on the chemical interactions of flour constituents. Functional properties are also considered important as they are detrimental factors for the interaction of flour constituents and product ingredients (like water, oil and sugars etc). Functional properties studied under this chapter were water absorption capacity, bulk density, foaming capacity, swelling power and emulsification properties. Functional properties tended to improve after germination of seed grains. Due to higher protein content and damaged starch water absorption capacity of legumes were reported higher after germination (1.27±0.02 for germinated kidney bean and 1.38±0.02 for chickpea), water absorption capacities of cereals ranged from 1.28±0.01 to 1.61±0.01. Similarly emulsification stability of legumes was also high and ranged between 58.62±0.04 to 58.08±0.06 after germination for chickpea and kidney bean. Germinated grains were found suitable for preparation of bakery products like biscuits and cookies. The degradation of starch and carbohydrate molecules makes flour unsuitable for bread preparation.
Effect of germination on the anti-nutritional factors was discussed in detail in chapter-VI. Anti-nutritional factors are quite important to observe the nutritional quality of grains. Oxalates, phytic acid, trypsin inhibitor activity, total polyphenol and tannin content were analyzed as anti-nutritional factors. Germination lowers the anti-nutritional factors to great extent. Most of the anti-nutritional factors were supposed to reduce during soaking process due to water soluble nature of most of anti-nutritional factors. Reduction of tannin was found higher in wheat and chickpea after germination. Near about 70% decrease in the total tannin content was observed for both seeds as a result of germination. Trypsin inhibitor activity was greatly reduced in pearl millet and about 48.89% decrease in the value was observed. Phytic acid reduction ranged from 27.16 to 54.64%, with lower changes in brown rice and higher in case of pearl millet.

Chapter-VII covers the most important nutritional element of food grains in the form of amino acid profiling. Generally, protein content is of quite high importance in food research due the concept of malnutrition across globe. Food grains contains higher amount of protein but the amount protein actually available to body is lower due to complexity and availability of amino acids. Effect of germination on the quality of proteins in terms of amino acid content, essential amino acid index (EAAI), nutritional index (NI), biological value (BV) and protein efficiency ratios (PERs) were discussed in this chapter. Further the essential amino acid were subjected to amino acid scoring on the basis of requirement and standards as provided by FAO/WHO (2013). Essential amino acid content was found higher in both legumes and improved further to 62.28 from 61.70% in chickpea, and to 60.26 from 52.83% in kidney bean. The amount of essential amino determines the amino acid scores of food grains, therefore as a result the amino acid score of the amino acid content of legume was higher. Breakdown of proteins during germination led to increase in the free amino acid content of seed grains.
Chapter-VIII deals with the development of bakery products from the composite flours of selected germinated cereal and legumes. Central composite rotatable design was used to optimize the flour proportion for the preparation of cookies prepared from composite flour. Effort was made to partially replace the wheat and triticale bases and fortification of appropriate level of cereal or legumes to formulate different type of cookies at optimum level of responses. Therefore cereal and legume proportion was taken and independent variables, whereas spread ratio, snap force and overall acceptability were taken as responses. Four different formulation of composite flour based on cereal and legume based fortification in wheat and triticale was optimized. Partial replacement of wheat in cereal blended formulation was achieved by fortification of 20.67g of pearl millet and 31.71g of brown rice, whereas legume blend of wheat was optimized with 31.19g of chickpea and 19.11g of kidney bean. Similarly, triticale based cereal fortified cookies were optimized with 22.67g of pearl millet and 23.15g of brown rice, whereas triticale based legume blend was optimized with 34.50g of chickpea and 15.13g of kidney bean.

Optimized composite flours (premix) and cookies prepared from the optimized composite flours, as discussed in chapter-VIII were subjected to characterization. Characterization parameters discussed in the present chapter involves the functional characteristic and pasting properties of germinated composite flour. Whereas cookies prepared from the optimized germinated composite flours were analyzed for compositional, functional, textural and sensory characteristic along with color characteristic. Fortification of germinated flours affects the characteristics of optimized cookies. Functional properties of blended flour were different from control sample and were slightly better due to higher protein content and more damaged starch. Legume fortified cookies were slightly softer in texture than cereal based cookies.
Chapter-X deals with the *in vitro* digestibility studies of formulated cookies and its nutritional status. *In vitro* studies, involved protein and carbohydrate digestibility studies. Protein digestibility of control sample was 51.54±0.05%. Higher protein digestibility was found in cereal blends with observed values of 69.45±0.03% for triticale based cereal fortified cookies followed by wheat based cereal fortified cookies (68.56±0.02%). Wheat based legume fortified blends closely followed wheat based cereal fortified cookies with *IVPD* of 67.53±0.04%. Nutritional status of the formulated products was observed on the basis of amino acid profile. The values of essential amino acid content for legume fortified cookies varied between 60.90±0.04% to 63.12±0.05% for triticale and wheat based cookies, respectively. Aromatic amino acid content was found lower in legume blended cookies, which were observed with 8.63±0.03% and 8.27±0.04% in triticale and wheat based cookies, respectively. Partial shelf life studies of the formulated product using single suitable packaging material for 90 days is also included in this chapter. Reduction of anti-nutritional factors enhanced the *in vitro* digestibility of cookies and fortification of different flour improved the nutritional status of optimized cookies. It was observed that the cookies were shelf stable even after 90 days of storage.

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