SUMMARY AND CONCLUSION

In the present research, studies on germination of cereal and legumes was conducted to formulate novel bakery product in the form of composite flour cookies. The product formulated was prepared from composite flour. To achieve the novel formulation from germinated cereal and legume grains, present research undergoes from various criteria which comprises the optimization of germination process, effect of germination on composition and functional characteristics. After the optimization of formulation, products were characterized and evaluated for its nutritional and textural properties. Shelf life study of optimized composite flour cookies was also carried out in the end.

Soaking proved to be detrimental factor for consideration of germination optimization. It is the initial process, where the quiescent viable seed initiates or prepare itself for the metabolic activities required for its growth and development. Certified seeds were chosen for the reason to avoid optimization under pre-determined factors like temp-time/RH combination conditions. Optimization was done on the criteria of selecting optimal soaking medium other than regular water. Therefore, solutions with ionic strength (sodium hydroxide, sodium bicarbonate, magnesium chloride) and without ions (distilled water) were considered for optimization experiments. Effect of soaking kinetics under different chemicals stresses generated novel data of soaking kinetics and germination index. However the previous existed data for soaking kinetics was based on the effect of temperature variations of soaking medium. Peleg’s constant was used by various researchers to understand soaking kinetics at different temperature variations.
In present research the Peleg’s model was exploited to evaluate the soaking kinetics under different chemical stresses. Peleg’s constants (K₁ and K₂) were affected by using different soaking mediums. As the rate and extent of moisture absorption varied among different soaking solution soaked grains, the dimensional analysis also varied along with. From the soaking kinetics and germination indices, it was concluded that distilled water could be used as an optimum medium for soaking and germination of the cereal and legumes studied, except pearl millet. Ionic solutions performed well in soaking studies but failed to exhibit good germination indices.

After optimizing the soaking medium for germination, selected seed grains were subjected to germination under appropriate conditions. Germination brought various biochemical changes in seed grains. On germination, quiescent seed grains became active and the reserve components were utilized for its growth in the form of cell material and energy for the processes. Carbohydrate acted as major food reserve for grains with starch as its major constituent. During germination complex carbohydrates were broken down into simpler sugars, which are more readily available for energy production through various biochemical pathways. As a result, reducing sugars and non-reducing sugars contents increased in germinated grains. On the other hand, starch molecule was degraded by the action of alpha amylase and as a result amylose and amylopectin content decreased, which justifies the increment of sugars. Increase in the free amino acids and decrease in the dry weight resulted in increment in overall nitrogen content of grains. Crude and dietary fiber content increased during germination due to the increment in cell wall building polysaccharides. Folic acid, which is a micro-nutrient in grains was also increased as a result of germination. Morphological studies has shown starch as the major structures associated with protein
matrices. SEM micrographs of germinated flour has shown disrupted and irregular surface of starch molecules associated with more protein matrices.

Compositional characteristics are directly related to functional properties of flour. Changes in the compositional characteristics brought changes in the interaction of molecules which affects the molecular level conformations and resulted in altered functional properties. After germination increment in water absorption capacity and oil absorption capacity was observed as a result of compositional changes. Functional properties are considered as biophysical properties due to the association of internal components to other ingredients like water and oil. Retention of water and oil greatly affects ingredients of product formulation and the final product. Effect of increment of protein and degradation of starch could physically be observed by the increment in water absorption and oil absorption of flours. Increment in the water absorption capacity was also due to damaged starch content which tended to absorb more water. Foaming and emulsification properties could attributed to the improvement in surface properties of proteins and its interaction with lipids. Improvement in the functional properties made flours more suitable to formulate bakery products like cookies. Damage of starch molecule make the germinated flour unsuitable for bread preparation.

Major problems of consuming un-processed grains was associated with the secondary metabolites or anti-nutritional content of grains, which interfered with digestibility and mineral absorption in humans. Soaking and germination lowered the anti-nutritional factors and therefore resulted in more digestible and nutritious grains. Trypsin inhibitor, phytic acid, polyphenols, tannins and oxalates were reduced significantly during germination in all the studied grains in present research. Reduction in those anti-nutritional factors could increase the digestibility and mineral availability of grains.
Amino acid profile of studied grains were varied significantly after germination. Due to the metabolic demand of cells, amino acids were synthesized and utilized from the reservoir pool of total amino acids. Most of the peptides were hydrolyzed to synthesize new amino acids to form components of cell material and energy requirement. Inter-conversion of amino acids like glutamic acid to histidine like essential amino acid occurred during germination, as a result non-essential amino acids were reduced to some extent with correspondingly increment in essential amino acids. With the increment in total essential amino acids, nutritional index and essential amino acid index has shown improvement. Amino acid scoring according to the reference values of FAO/WHO has shown the improvement in the quality of protein and availability of essential amino acid in the germinated grains. Overall nutritional profile on the basis of amino acid profile improved due to germination.

Germination process improved the various necessary characteristics of seed grains, therefore product with higher nutritional profile was targeted by partial replacement of native flour i.e. wheat and triticale. Optimization was carried out by using response surface methodology and central composite rotatable design. Wheat and triticale were subjected to partially replace by either cereal or legumes, therefore other selected grains (pearl millet, brown rice, chickpea and kidney bean) were selected as independent variables. In the process four different type of formulations were prepared namely, wheat based cereal fortified, wheat based legume fortified, triticale based cereal fortified and triticale based legume fortified. Optimization was done by analyzing the different level of formulations on the basis of responses like spread ratio, snap force and overall acceptability of cookies prepared. 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 formulated germinated composite flours were characterized on the basis of their functional and pasting properties whereas optimized cookies were analyzed for texture properties, compositional analysis and color characterization. Variation in the functional properties of resultant composite flour was observed due to interaction between the components of different flours. The values observed were not based on the resultant effect of different flour. Pasting properties were greatly influenced by germination and blending of different flours. Compositional analysis of different flour has shown the high protein content in legume fortified blends, whereas overall composition of each blend was observed better than control samples. Hardness of control sample was higher whereas cereal fortified cookies were slightly lower in hardness. Legume blended formulations resulted into softer cookies. Cereal fortified cookies were darker in color after baking whereas legume fortified cookies were slightly darker than control cookies.

Cookies prepared from raw flour were observed with lower digestibility due to factors like complex carbohydrates and presence of anti-nutritional factors. Protein digestibility which was limited due to trypsin inhibitors in control cookies was increased in germinated and blended formulations, due to reduction of trypsin inhibitor activity. Increment in carbohydrate digestibility was due to breakdown of complex carbohydrates and disrupted starch molecules during germination. Amino acid profile of formulated cookies was higher as compared to control. Shelf life studies indicated that the formulated cookies were shelf
stable and not much variations were observed in the shelf life parameters even at 90th day of storage.

From the present research it was concluded that germination enhanced the nutritional attributes of seed grains in the form of composition, amino acid profile and in vitro digestibility. The problems associated with the utilization of raw seed grains, like flatulence, lower digestibility and lower availability of nutrients could be overcome by mere employing the germination process. Breakdown of complex components during germination into simpler components and more digestibility, provides food with high glycemic index and more available nutritive product at same time by maintaining the energy-nutrition balance.

Germinated flours were found unsuitable for bread making process due to damaged starch but it was found more suitable for biscuit and cookies formation. Wheat and triticale type base ingredient material could be replaced by addition of other germinated cereal and legumes. Of the different formulations optimized, wheat based cereal fortified cookies were of preference by panelists on the basis of overall acceptability. Whereas, legume based cookies of both wheat and triticale were of similar acceptance on the sensory scale.

On the basis of compositional characteristics, legume based cookies could be preferred, due to higher protein and crude fiber content. Wheat based legume cookies were found with higher protein content which varies significantly (p≤0.5) from the other formulated cookies. Fortification and germination of seed grains provides more nutrition rich composite flours cookies as compared to control sample (prepared from raw grains wheat flour). In vitro digestibility studies has shown that the formulated cookies were of high digestibility. Wheat based cereal fortified cookies were observed with higher carbohydrate digestibility, whereas the protein digestibility of the same was closely followed by triticale
based cereal fortified cookies. Whereas the nutritional profile of cookies on the basis if amino acid profile was higher for legume fortified cookies. Sensory analysis of product during partial shelf life studies, reflects the acceptability of all the optimized formulated cookies on the 90th of storage in comparison to control cookies.

Therefore, it is feasible to produce more nutritious and highly digestible cookies by combining different germinated flours with good nutritional profile, digestibility and acceptability.

**Further research recommendation**

- Implication and applications of Peleg’s equation on basis of factors other than temperature which affects soaking process.
- In depth studies of ionic solutions and cell wall component interactions during soaking process and its relation to germination.
- Exploration of more cereal and legume blends to fill in the lacunae of nutrients.
- Interaction of amino acids and functional properties of different flours to understand, modify and improvement of functional characteristic of flours.
- Improvement of traditional methods to yield more functional components and highly nutritious products.