POST GRADUATE DIPLOMA
IN
BAKERY SCIENCE AND TECHNOLOGY

PGDBST – 02

FUNCTIONALITY OF WHEAT FLOUR COMPONENTS & BAKERY INGREDIENTS

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UNIT I: PROTEINS AND ENZYMES

STRUCTURE

1.0 OBJECTIVES

This unit is designed to explain the following concepts of wheat proteins and enzymes:

- Composition and classification of proteins
- Structural properties of proteins
- Protein functionality in bakery products
- Manufacturing techniques of wheat gluten
- Uses and functionality of gluten
- Functionality and properties of wheat enzymes

1.1 COMPOSITION AND CLASSIFICATION

In 1907 Osborne classified proteins of wheat endosperm into non-gluten forming and gluten forming groups when wheat flour is wetted and mixed with water. The non-gluten forming proteins are albumins and globulins, which are washed out to a large extent along with the starch during the gluten-starch separation step accomplished normally with 0.5 M NaCl. A dialysis step is often used to separate the albumins and globulins. Dialysis against water causes the globulins to precipitate, while the albumins remain in solution. The non-gluten protein class accounts for approximately 10-20% of the total flour proteins, and their amounts remain relatively constant among wheat varieties.

Traditionally gluten forming proteins, which represent 80-90% of the total proteins of wheat flour, have been classified into two major groups, viz. gliadin and glutenin, based on their extractability and unextractability, respectively, in aqueous alcohol. The term gliadin and glutenin are the specific names for the wheat proteins corresponding to the generic term's prolamin and glutelin of all cereal proteins. It is believed that Taddei first coined the name gliadin and zimone in 1819 for aqueous alcohol extractable and unextractable fractions of gluten, respectively. The name glutenin was proposed later by Osborne in preference to Taddei's zimone because

the latter term was based on the Greek word for ferment implying an enzyme activity. The term gliadin was retained, however.

Neither of these groups are considered to consist of pure proteins, and a considerable amount of overlap between these groups may occur depending on the exact extraction conditions, such as time, temperature and type, as well as concentration, of alcohol used. There is no fundamental basis for classifying the gluten proteins on the basis of aqueous alcohol extractability, although such a classification does have technological significance. Gliadin and glutenin are known to impart entirely different physical properties to the gluten network in wheat flour dough. Gliadin behaves mainly as a viscous liquid when hydrated and imparts extensibility, allowing the dough to rise during fermentation, whereas glutenin provides elasticity and strength, preventing the dough from being over-extended and collapsing either during fermentation or in baking.

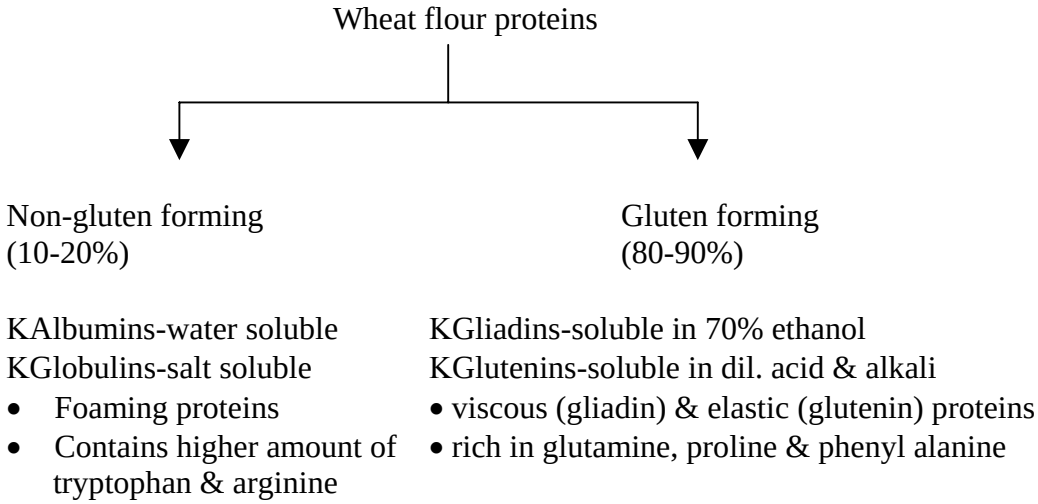


Figure 1.1 Classification of wheat flour proteins according to Osborne

Shewry and colleagues have proposed an alternative classification in 1986 that reflect biological, chemical and genetic relationships among component polypeptides of the gluten complex. They divided gluten proteins into three main categories namely: sulphur-poor prolamins, sulphur-rich prolamins and high molecular weight (high M_r) prolamins (**Fig 1.2**). All these gluten protein groups are considered typical prolamins because they are rich in proline and glutamine amino acid residues and are extractable, at least partially, in aqueous alcohol, particularly after addition of reducing agent.

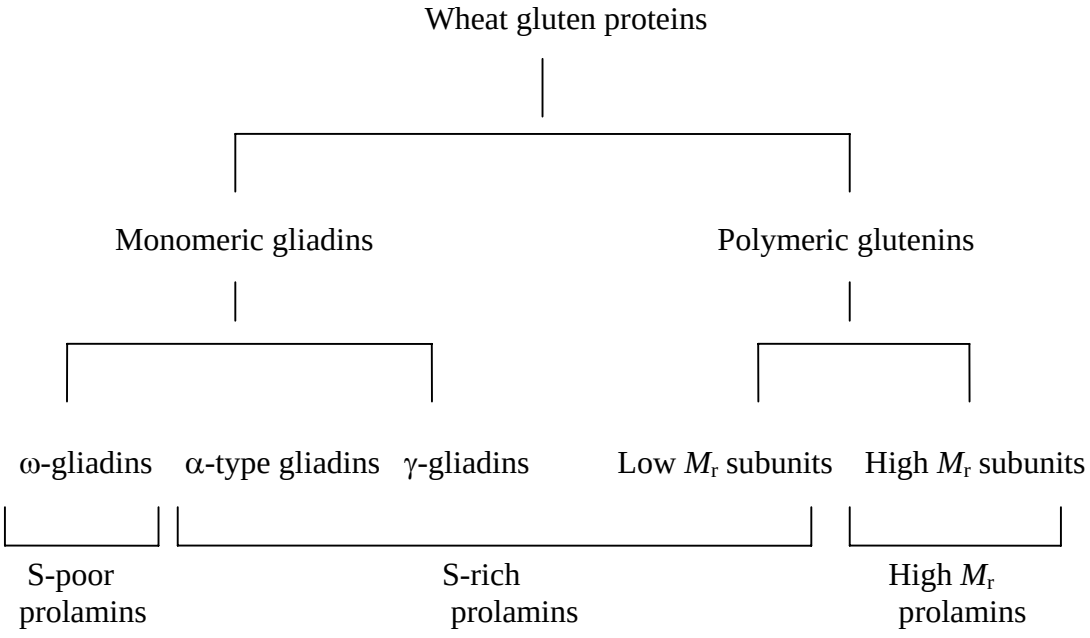


Figure 1.2 Classification and nomenclature of wheat gluten proteins by Shewry & colleagues

1.1.1 GLIADINS

The gliadins are usually classified into four main sub-categories, α-, β-, γ- and ω-gliadins, in decreasing order of electrophoretic mobility under acidic conditions and increasing order of relative molecular mass (M_r). Introduction of new protein separation techniques such as two-dimensional electrophoresis and reversed-phase high performance liquid chromatography (RP-HPLC) have made it possible now to separate gliadins into many individual polypeptides.

Amino acid sequencing has revealed that the α- and β- gliadins are structurally closely related polypeptides and therefore both of these gliadin polypeptides have been classified into one group, α-type gliadins. The amino acid compositions and M_rs of α-type gliadins are quite similar to γ-gliadins. However, these groups of gliadin polypeptides show some striking differences from ω-gliadins.

The ω-gliadins are rich in glutamine, proline and phenylalanine, these three representing about 80% of the total residues, but contain few or no methionine and cysteine (sulphur containing amino acids). On the other hand, the α-type and γ-gliadins are relatively rich in sulphur containing amino acids but have relatively fewer proline, glutamine and phenylalanine residues. The M_rs of α-type and γ-gliadins are between 30,000-45,000, whereas, ω-gliadins generally have M_rs of 44,000-80,000. The γ-gliadins, in general, have somewhat higher M_rs than α-type gliadins.

1.1.2 GLUTENINS

The polypeptide components of glutenin are fractionated into low and high M_r subunits by SDS-PAGE under reduced conditions. The high M_r subunits (also known as A subunits) of glutenin are the largest polypeptides and contain the highest level of glycine residues among gluten proteins. Their M_rs, measured by SDS-PAGE, range from 80,000-160,000. However, SDS-PAGE over-estimates the M_rs, and the true M_rs obtained from the amino acid sequences give much lower range of about

63,000-88,000. The high M_r subunits are further divided into x-type and y-type. The x-type are somewhat larger polypeptides (true M_rs 83,000-88,000) while the y-type are smaller with M_rs of 67,000-74,000.

The low M_r subunits of glutenin, after reduction of the disulphide bonds, can be divided into two main groups; a major group of basic proteins (B subunits) with M_rs of 42,000-51,000 and a minor group (C subunits) with M_rs of 30,000-40,000. Because of their similar molecular sizes; the low M_r glutenin subunits are difficult to separate from α-type gliadins and γ-gliadins by SDS-PAGE. This has hampered studies aimed at determining the functional importance of low M_r glutenin subunits in contrast to those of high M_r subunits. However, electrophoretic and solvent fractionation techniques have been developed recently to separate the low M_r glutenin polymers from monomeric gliadins and high M_r glutenin polymers.

Marion and co-workers developed a new and improved method using the detergent Triton X-114, which, according to them, provides excellent separation between gliadin and glutenin. Melas and colleagues have introduced a protein fractionation scheme based on selective precipitation with acetone that yields large amounts of purified low and high M_r glutenin polymers. It has long been thought that the gliadin/glutenin ratio, low/high M_r glutenin subunit ratio and the properties of these individual groups of polypeptides are primarily responsible for the inter-cultivar variation in end-use quality.

1.2 STRUCTURAL PROPERTIES

The structural features of proteins depend on composition and sequences of their amino acids, which determine their ability to participate in chemical reactions through covalent and non-covalent interactions. Disulphide bonds are the principal covalent bonds within and between gluten polypeptides and they are of considerable importance technologically. Non-covalent interactions include ionic, hydrogen and van der Waals interactions, and are generally much weaker than covalent bonds. Non-covalent interactions, especially hydrogen bonds, are also of considerable technological importance for gluten proteins. In addition, hydrophobic interactions

play an important role and occur between apolar groups of amino acid chains. The most significant covalent bonds evident in the structure of gluten proteins are disulphide linkages. Gliadins have either intramolecular (as in α-type and γ-gliadins) or no (ω-gliadins) disulphide linkages, whereas in glutenin they are both inter- and intramolecular.

Hydrogen bonds are formed as a result of the affinity of hydrogen atoms in hydroxyl, amide or carboxyl groups for oxygen in carboxyl or carbonyl groups. Gluten proteins are rich in highly polar amino acids, in particular glutamine. Glutamine constitutes over 33% of the amino acids present in gluten; the amide group in glutamine actively participates in hydrogen bonding and, in fact, forms two hydrogen bonds per glutamine residue. Gluten proteins also contain large proportions (~30% of total amino acid residues) of apolar amino acids, such as phenylalanine and proline, which are considered potential source of hydrophobic interactions. The apolar residues in amino acids are associated with one another in aqueous medium. The high average molecular weight of glutenin polymers and their strong aggregation tendency are due to inter-polypeptide chain disulphide bonds, the hydrogen bonding potential of the unusually large numbers of glutamine side chains, the potential for apolar bonding of the many apolar side chains, and the low ionic character of gluten proteins.

Another important feature of gluten proteins is that they have a very low charge density. This is due to their low level of basic amino acids, such as lysine, histidine, arginine and tryptophan, and also due to the fact that glutamic and aspartic acids occur mainly as amides. A consequence of this low charge density is that the wheat gluten proteins are not repelled by mutual charge repulsion and associate strongly by non-covalent interactions. Such behaviour is important to baking technology in that it results in the ability of gluten proteins to form viscoelastic gluten and a gluten film network that is essential for gas retention.

In recent years a great deal of knowledge about the structure of gluten proteins has been acquired through the application of gene sequencing techniques. The major

information has come from cloning of genes for gliadin and glutenin polypeptides and deduction of complete amino acid sequences from the DNA sequences of the respective genes. Comparison of these sequences (**Fig. 1.3**) reveals that all types of gluten protein polypeptides, in general, have at least two or three distinct structural domains, that is, a central repetitive domain, flanked by non-repetitive C- terminal and N-terminal domains.

The S-rich prolamins are characterised by a shorter repetitive domain and a longer C-terminal domain compared with high M_r prolamins and S-poor prolamins. S-rich prolamins have their cysteine residues in the C-terminal domain, the only exception being the low M_r subunits, which also contain one cysteine residue in the N-terminal domain. S-poor prolamins have no cysteine residues as indicated from ω-secalin of rye, a homologue of wheat ω-gliadins.

In contrast, high M_r prolamins have the majority of their cysteine residues (3 and 5 in x-type and y-type subunits, respectively) in the N-terminal domains and only one in the C-terminal domain. Several y-type subunits also have one additional residue in the central repetitive domain towards the C-terminal end, and x-type subunit 5 has one residue close to the N-terminal end of its central domain.

Total numbers and relative positions of cysteine residues are important for polymer size and the different polymerisation behaviour of gliadins and glutenin subunits. The presence of cysteine residues in the form of intramolecular disulphide bonds in gliadins and inter- and intramolecular disulphide bonds in glutenin subunits is due to the fact that gliadins have even numbers of cysteine residues whereas glutenin subunits have odd number of residues (analysed so far) within a single structural domain (see **Fig. 1.3**). The relative position of cysteine residues and the manner of chain folding are also important for this difference. Among the S-rich prolamins, the polymerisation behaviour of low M_r subunits of glutenin is attributed to their ability to form intermolecular S-S bonds, which distinguishes them from gliadin polypeptides.

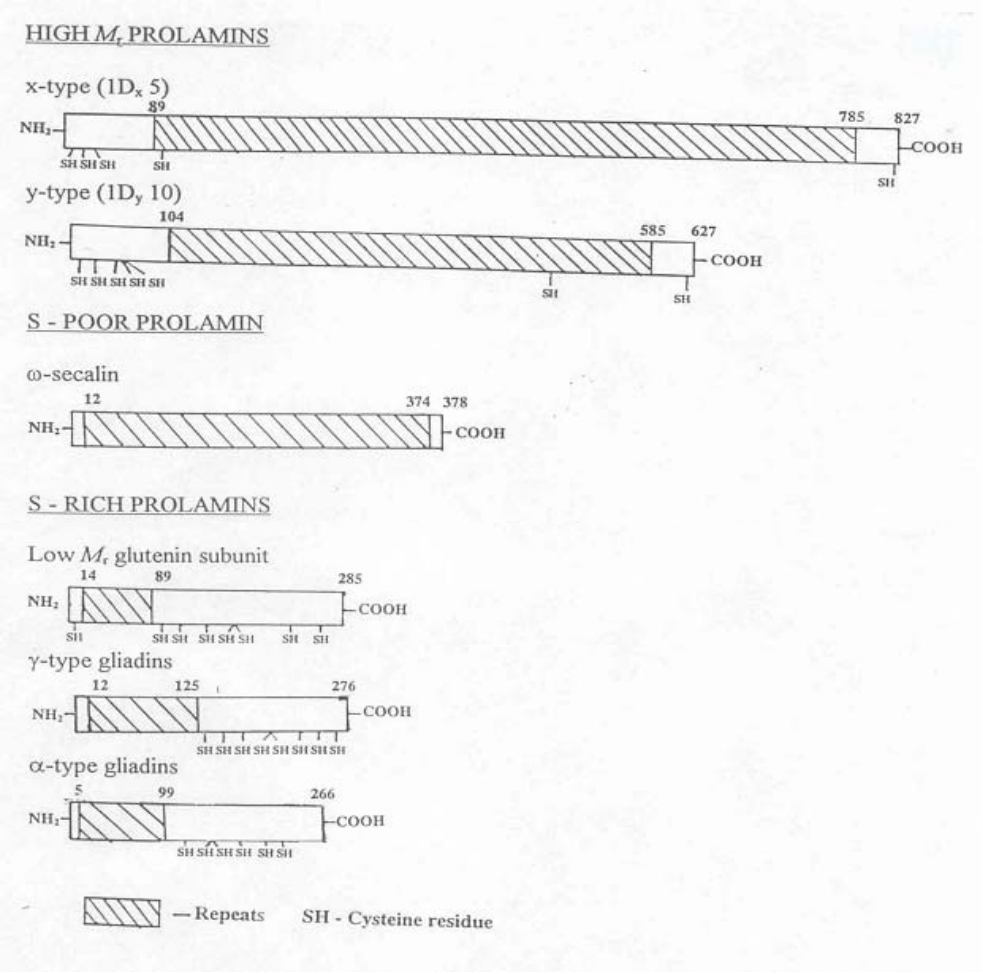


Figure 1.3 Structural model of gluten polypeptides based on comparison of the amino acid sequences of typical gluten proteins of wheat and ω-secalin of rye (a homologue of ω-gliadins). Representations are very approximately to scale.

1.3 PROTEIN FUNCTIONALITY IN BAKERY PRODUCTS

Protein content in wheat flour generally ranges from 8-18 per cent. Fermented bakery products such as bread and buns require higher amount (> 10 per cent) of good quality protein for gas retention and dough rise during fermentation or early stages of baking. On the contrary, soft wheat products such as biscuits, cakes and cookies can be produced using low protein flour (8-9 %). Lower amount of

proteins confers dough extensibility and spreadability of dough that is considered desirable for texture and quality of soft wheat products.

1.3.1 ROLE OF PROTEINS IN BREAD MAKING

Protein quantity and quality

It has long been established that the rheological properties and bread making performance of wheat flours are related to the quantity and quality of their proteins. The relationship between protein content and bread making performance (measured as loaf volume) is essentially linear within a wheat variety over the normal range of protein contents encountered in commercial wheat flours (**Fig. 1.4**). The differences in the slopes of the regression lines among wheat varieties reflect differences in their protein quality. Higher slopes characterize wheat variety with high bread making performance.

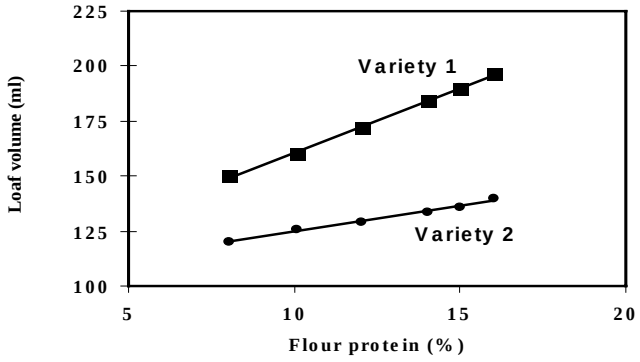


Figure 1.4 Bread making performance of two different wheat varieties as a function of protein content.

When the total protein content of a wheat grain increases, the total amount of gluten proteins also increases, but, the amount of the non-gluten forming proteins (i.e. albumins and globulins) changes very little. For this reason, there is a close positive relationship between the total protein content and gluten content of wheat flours. Thus, wheats of high-protein content usually have a higher proportion of gluten proteins compared with those with lower protein contents.

Fractionation and reconstitution studies (i.e. experiments in which the different flour constituents are first separated and then systematically exchanged between reconstituted flours of good and poor quality) have confirmed that the gluten proteins are primarily responsible for quality differences among wheat varieties. Similar studies have generally shown that the non-gluten proteins do not play a significant role in the variation in bread making quality that occurs amongst different varieties of wheat. It has been suggested, in fact, that these proteins may be omitted from reconstituted flours without detrimental effects on their baking qualities, provided steps are taken to ensure that gas production is not limited.

Gluten proteins

A number of research workers have made considerable efforts over many years to elucidate which specific gluten protein fraction is responsible for flour quality. The relative importance of gluten fractions in bread making is assessed usually either by a correlation approach, which involves surveying a range of genotypes, or by the fractionation and reconstitution technique. The correlation studies give clues about the association of protein composition with bread making quality. However, the fractionation and reconstitution technique provides direct evaluation of gluten protein functionality. Reconstitution studies, on the other hand, are not considered suitable for evaluating the relative contributions of individual polypeptides. For this purpose, genetic lines are used in which a specific polypeptide is either not expressed or in which expression is enhanced.

In reconstitution experiments, the gluten proteins are first separated into sub-fractions and then either their amounts are varied in a given flour or an equivalent amounts of these fractions are interchanged between flours of diverse bread making quality. The solvents most commonly used for this purpose are aqueous ethanol (70%, v/v) and dilute acids, such as acetic acid, lactic acid and hydrochloric acid. Using these solvents, most gliadins are recovered in the extracted phase on centrifugation and glutenin remains in the unextractable phase. In reconstitution

experiments, it is important to take precautions in order to preserve the functionality of the flour components. This is generally checked by reconstituting all the flour constituents in the same proportions as in the original flour and then testing their dough mixing properties and carrying out a baking test to ensure that their quality parameters are unchanged. It is generally agreed that the bread making potential of wheat flour is related to the glutenin proteins. As a result, research on the glutenin proteins has been intense. Before discussing the role of glutenin polypeptides in relation to bread making, the importance of the gliadin/glutenin ratio will be considered.

Gliadin to glutenin ratio

Differences in the gliadin to glutenin ratio among wheat cultivars have long been considered an important source of inter-cultivar variation in physical properties and bread making quality. The technological significance of gliadin and glutenin in bread making has been attributed to their contribution to dough extensibility and elasticity, respectively. Doughs that are too elastic and inextensible or *vice versa* give poorer bread making performance than do doughs that have an appropriate balance of extensibility and elasticity. Recently it has been shown that addition of complete total gliadin and its subgroups (α-, β-, γ- and ω- gliadins) substantially improved bread making quality, as measured by loaf volume. These results are of special interest considering the known relationships of glutenin to bread quality. With this background, it was quite unexpected that a positive relationship between gliadin proteins and bread making quality might exist.

Molecular size distribution

Molecular size distribution has been considered another important factor in relation to functional properties of flour. Gel filtration chromatography studies have indicated that the glutenin fractions of flours with longer mixing times have a higher average molecular weight than the glutenin fractions of short mixing flours. Flours

with short mixing times give doughs that break down rapidly during mixing and that are easily extensible. Such flours are considered unsuitable for bread making. Conversely, flours with longer mixing times are noted for doughs of high mixing stability and greater resistance to extension and which perform well in bread making. However, flours that require very long mixing times may prove undesirable under practical bakery conditions.

Glutenin polypeptides

In order to understand the molecular basis of bread making quality, numerous studies have been conducted during the last decade on the structural aspects and the role of glutenin subunits, specifically the high M_r subunits, in bread making. These studies used genetic lines in which specific polypeptides are either not expressed or are enhanced. This interest in high M_r subunits of glutenin stems largely from the pioneering work of Payne and colleagues, who demonstrated correlations between the presence or absence of particular high M_r subunits and bread making performance in a number of studies involving wheats from different countries and progenies of crosses between cultivars of diverse quality.

Upto 20 different high M_r subunits have been identified in different bread wheats. Each bread wheat cultivar contains 3-5 high M_r subunits, which together account for about 1% of the dry weight of the mature endosperm of a wheat grain. This indicates that, although high M_r subunits are quantitatively minor, they are, nevertheless, functionally important polypeptides of gluten proteins.

The high M_r subunits of glutenin are encoded at the *Glu-1* loci on the long arms of the chromosomes 1A, 1B and 1D. These loci are designated as *Glu-A1*, *Glu-B1* and *Glu-D1*, respectively. *Glu-1* quality scores are assigned to the individual subunit or subunit pair based on their values determined by the SDS-sedimentation test, an indirect measure of bread making quality (**Table 1.1**).

The genes for x-type and y-type subunits are closely linked in the case of the 1D alleles and some 1B alleles, and, therefore, *Glu-1* scores are assigned to subunit pairs

rather than individual subunits for such alleles. The *Glu-1* score of a cultivar is calculated by summing the scores of the subunits it contains. The *Glu-1* scores of bread wheats usually range from 3 (for poor bread making quality) to 10 (for good bread making quality).

Table 1.1 *Glu-1* quality scores assigned to individual high M_r subunits or subunit pairs of glutenin

Locus			
Glu-A1	*Glu-B1*	*Glu-D1*	*Glu-1* score
-	-	5+10	4
1	17+18	-	3
2*	7+8	-	3
-	13+16	-	3
-	7+9	2+12	2
-	-	3+12	2
Null	7	4+12	1
-	6+8	-	1
-	20	-	1

Scores are ranked from 1 to 4, indicating poor and good bread making quality, respectively.

The *Glu-1* score is positively correlated with bread making performance and 47-60% of the variation in bread making quality could be accounted for by the variation in high M_r subunits of glutenin. Correlation studies with near-isogenic lines [i.e. lines that differ in polypeptide(s) expressed at one locus] have shown that the number and quantity of high M_r subunits of glutenin largely control the mixing time and bread making performance of a flour. It is also noted that the good bread wheats contain superior high M_r subunits, such as subunits 5+10, 1, 2*, 17+18 and 7+8, and the poor bread making wheat cultivars generally have inferior high M_r subunits, such as 2+12, 6+8, 20 or null (i.e. silent) allele.

Although it is now evident that the high M_r subunits of glutenin play a significant role in bread making performance, the basis of the differential effect of various glutenin subunits on bread making quality of a flour remains to be defined. It

is reported that the alleles at the *Glu-B1* and *Glu-D1* loci produce high M_r subunits (17+18 and 20 or 5+10 and 2+12) in similar amounts. This means that the qualitative differences in high M_r glutenin subunits may be responsible for the differences in the bread making quality among wheat varieties. This is consistent with the observations that the superior subunit 5 has one additional cysteine residue and has a greater M_r than the inferior subunit 2. The superiority of the subunits 17+18 over subunit 20 in the case of genome B has been attributed to the number and/or position of the cysteine residues. Recent studies indicate that high M_r subunits are not the only determinants of bread making quality. Therefore, there is a need to obtain more information on the role of low M_r glutenin subunits in bread making. Such information may help to resolve the apparent anomalies experienced in the study of high M_r polypeptides and bread making performance of wheat varieties.

1.3.2 ROLE OF PROTEINS IN BISCUITS, CAKES & COOKIES

Wheat varieties are grouped as hard and soft wheats. Hard wheat yields strong flour with higher protein content. On the other hand, soft wheat on milling yields weaker flour with lesser protein content. The strong flour are generally used in the production of yeast leavened bakery products such as bread and buns, whereas the weak flour are found suitable for the production of cookies, cakes, biscuits and crackers. Weak flour proteins do not form a continuous gluten matrix when flour is mixed with water due to lesser quantity and basic quality characteristics of gluten proteins in weak flour. The conditions of dough preparation for soft wheat products such as low levels of water addition and higher amounts of sugar and fat in the formulation with low energy inputs favour dough preparation that is crumbly and extensible but lacks strength and elasticity. Dough with such characteristics extends more when subjected to higher temperature in the baking and more numbers of biscuits are obtained from a given mass of dough.

Higher amounts of gluten proteins are not desirable for biscuit and cookie production because large amounts of gluten proteins prevent spread of dough and

hampers molding of dough to specific dimension and shape. The larger amounts of gluten proteins make the dough stronger and elastic that contracts/recoils after sheet formation. The glutenin proteins are held responsible for the strength and elastic nature of dough or gluten. These proteins favour gas retention and hence volume of bakery products. Since, in biscuits and cookies making, large volume is not desirable, therefore, lesser glutenin proteins in flour would favour desired soft wheat products. On the contrary, the gliadin proteins are smaller and globular in nature and are credited with less surface areas for interaction with other flour constituents, and hence these proteins make the dough more extensible acting analogous to ball bearing action. Extensibility is a desirable character for biscuit and cookie dough and thus, higher proportion of gliadin proteins in flour will be desirable for biscuit and cookie production.

Cookie diameter and cake volume correlate positively with soft textured wheats having lower protein contents, which produce flours with smaller particle size. Hard textured wheats having better milling quality are more coarsely granulated during milling and hence produce smaller cakes and cookies.

Soft wheat with lower protein content produces flour with following characteristics those are considered suitable for the production of good quality cakes, cookies and biscuits:

- Low water absorption
- Low starch damage content
- Fine flour granulation
- Low to medium mixing requirements

The water absorption of a flour depends largely up on the protein and starch damage contents. For low moisture products like biscuits and cookies, the amount of water used to make a dough should be minimum so flour of low water absorption having low protein and low starch damage contents is favoured.

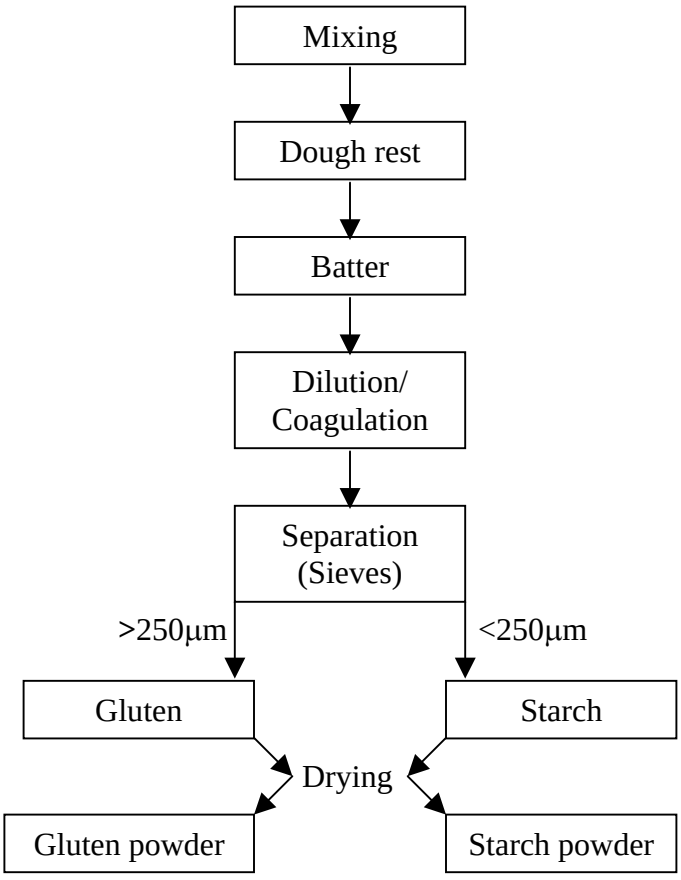
1.4 MANUFACTURING TECHNIQUES OF WHEAT GLUTEN

1.4.1 GENERAL PROCESS

Wheat gluten is the water-insoluble complex protein, which is separated from wheat flours. The separation process is accomplished by physical means from aqueous flour suspensions without additives of any kind, and the product is thus a natural food protein. In its freshly extracted wet form it is known as ‘gum gluten’ which when dried yields a cream coloured, free flowing powder of high protein content (75-80%) and bland taste. When rehydrated, it regains its original intrinsic viscoelastic properties, i.e. chewing gum like properties. The flow sheet and configuration of the wheat gluten and starch separation system is explained below. In this process a batter is made from dough. The batter is the flour suspension. The batter is then separated into gluten and starch using screens, decanters or hydrocyclones. For a good separation the coagulation of small gluten particles into larger ones is of paramount importance. The process details follows. Dough is prepared by mixing weighed quantity of flour and 60% of water using a Hobart type mixer. Dough is then rested for some time. Next, the dough is diluted with equal weight of flour with water under continuous mixing. This results into a system known as batter. This batter is transferred to the dilution and coagulation tank by a pump. The batter is further diluted with eight times the original weight of flour with water to initiate gluten coagulation. The slurry is separated into gluten and starch fractions by vibrating sieves (>250μm gluten and < 250μm starch). Fresh water is sprinkled over the sieves for washing. The sieves are emptied continuously by the vibrating action. The starch can be concentrated using centrifugation operation. The wet gluten and starch fractions are dried separately using vacuum shelf drier. The separated processing water can be recycled and used for dough making, suspension

and dilution. In this way water consumption can be substantially reduces. The system can be scaled up since the sieves are emptied continuously.

(b) Flow Sheet



Procedure of gluten separation from wheat flour

1.4.2 INDUSTRIAL PROCESS

At industrial scale gluten can be separated from wheat flour using two processes, namely Martin process & Raisio process. In Martin process the flour is mixed with water to develop the dough. The dough then rested under water. The dough is washed later with water. In Raisio process, flour is just slurried with excess of water and the dough is not developed during mixing. The Martin process uses more volume of water for separation of gluten, and hence affluent generation is more

in this process. The rehydration capacity of gluten powder prepared by the Martin process remains better.

INTERNATIONAL STANDARD FOR WHEAT GLUTEN POWDER

Protein (dry basis)	80% Min.
Moisture	10% Max.
Ash	2.0%Max.
Fat (Ether Extracted)	2.0%Max.
Fibre	1.5%Max.

1.5 USES AND FUNCTIONALITY OF GLUTEN

The ability of wheat gluten to form a viscoelastic mass when fully hydrated sets it apart from all other commercially available vegetable proteins. Gluten has gained wide acceptance in the food processing industries because of its unique physical properties, such as viscoelasticity, film-forming ability, themosetting properties and high water absorption capacity. Its viscoelastic properties improve dough strength, mixing tolerance and handling properties in a bread making process. The film forming property of hydrated gluten is a result of its elasticity. The film forming ability of gluten enhances gas retention and controlled expansion for improved volume, uniformity and texture of baked products; its thermosetting properties contribute necessary structural rigidity and bite characteristics; and its very high water absorption capacity improves baked product yield, softness and shelf-life.

The most fundamental use of vital wheat gluten is in the adjustment of flour protein level so as to make use of a flour more versatile. This practice is very common in USA, Canada, Australia and Europe. With increased emphasis on plant breeding to produce higher yielding wheats, there has been an associated decline in wheat protein content, thereby increasing the use of gluten supplementation. Use of gluten in wheat flour enables us to transform wheat into numerous value-added products. Vital wheat gluten can be used in multigrain, high fibre and other specialty

breads at levels ranging (flour basis) from 2% to 10%. In hamburger and hot dog buns gluten can be used to improve strength of hinge. In flaked cereals, wheat gluten provides not only the protein desired for nutritional claims but also helps bind any vitamin-mineral enrichment components to the cereal grain during processing. The unique adhesive, cohesive and film-forming characteristics of hydrated vital gluten and its thermosetting properties form the basis of various types of applications in meat, fish and poultry products. Wheat can also be used in other commercial products, such as sausage products, pizza toppings, meat analogues, nutritional snacks, etc. Gluten can also be beneficially used in breakfast cereals, pasta, nutritional snacks, extruded ground meat products, textured protein, meat analogs and fabricated steaks. Wheat starch the co-product of gluten manufacturing also finds wide applications in food industry. The world use of wheat for starch production has increased from 1.1 million tonnes in 1980 to about 4.0 million tonnes.

1.6 ENZYMES OF WHEAT

Wheat grains contain a large number of enzymes. The levels of enzymes vary in grains due to variation in genetic make up of varieties and climatic conditions during growing and harvesting. The location of enzymes is not uniform throughout the wheat seed. Many of the enzymes are found in the outer aleurone and bran layers of the kernel and in the germ. This means that on milling, enzymes are unevenly distributed in different fractions, the endosperm fractions generally having the lowest enzyme activity. On the other hand, flour fractions rich in bran and dietary fibre may also be rich in endogenous enzymes. A combination of various enzymes have a positive effect on volume, colour, taste, aroma, crust and crumb texture, crumb softness, freshness and shelf life of the baked product.

Alpha-amylase plays most important role in the wheat processing into bakery products particularly bread. Alpha-amylase hydrolyses starch in to sugars, which are further, fermented by the yeast. The increased bread volume may partly be due to the

increased yeast activity. The enzyme- induced changes in dough rheology are also a major reason for the increased bread volume. Owing to softening, the dough can expand more, producing increased oven-spring. The gas retention properties of the dough may also be improved, perhaps because of the different composition and improved stability of the liquid film at the gas-liquid interface.

The alpha-amylase also delays bread staling rate. Alpha-amylase produces low molecular weight branched-chain starch polymers as hydrolysis products, which interfere with amylopectin recrystallization. It has also been suggested that the dextrins produces by alpah-amylase interfere with the interactions between the swollen starch granules and the continuous protein network in the bread, and that the cleavage of bonds in amylose and amylo- pectin promotes the formation of amylopectin-lipid complexes.

Amyloglucosidase (glucoamylase) is also a member of the family of amylases. This enzyme liberates glucose from the chain ends and is also capable of hydrolyzing branched starch molecules (amylopectin). The enzyme is used to give color and flavor to the crust, and the liberated glucose participates in Maillard reactions.

Hemicellulase is the generic name for a complex group of enzymes, which can use hemicellulose as a substrate. However, each enzyme has its own characteristic specificity towards this heterogeneous substrate. Endoxylanase and exoxylanase are examples of enzymes that belong to the hemicellulase group. Hemicellulose in flour is mainly found as arabinoxylan and even though the arabinoxylan content in flour is only 3%, it binds up to 30% of the added water. Water is released in the dough by the partial hydrolysis of this substrate by endoxylanase. As a result, the dough becomes softer, and its machinability is improved. The final result is that, during baking, crumb formation is delayed, and the better oven-spring gives the bread larger volume and a softer, more delicate crumb.

1.7 SUMMARY

In 1907 Osborne classified proteins of wheat endosperm into non-gluten forming and gluten forming groups when wheat flour is wetted and mixed with water. The non-gluten forming proteins are albumins and globulins. Traditionally gluten forming proteins, which represent 80-90% of the total proteins of wheat flour, have been classified into two major groups, viz. gliadin and glutenin, based on their extractability and unextractability, respectively, in aqueous alcohol. The gliadins are usually classified into four main sub-categories, α-, β-, γ- and ω-gliadins, in decreasing order of electrophoretic mobility under acidic conditions and increasing order of relative molecular mass (M_r). The polypeptide components of glutenin are fractionated into low and high M_r subunits by SDS-PAGE under reduced conditions. Comparison of complete amino acid sequences reveals that all types of gluten protein polypeptides, in general, have at least two or three distinct structural domains, that is, a central repetitive domain, flanked by non-repetitive C- terminal and N-terminal domains. Protein content in wheat flour generally ranges from 8-18 per cent. Fermented bakery products such as bread and buns require higher amount (> 10 per cent) of good quality protein for gas retention and dough rise during fermentation or early stages of baking. On the contrary, soft wheat products such as biscuits, cakes and cookies can be produced using low protein flour (8-9 %). Lower amount of proteins confers dough extensibility and spreadability of dough that is considered desirable for texture and quality of soft wheat products.

Wheat grains contain a large number of enzymes. The levels of enzymes vary in grains due to variation in genetic make up of varieties and climatic conditions during growing and harvesting. A combination of various enzymes have a positive effect on volume, colour, taste, aroma, crust and crumb texture, crumb softness, freshness and shelf life of the baked product.

1.8 KEY WORDS

Wheat gluten: It is a complex protein which is developed due to interaction of wheat proteins when flour is mixed with water. This protein is isolated from developed dough by washing it with water. The water dissolves all water soluble components which are discarded and the remaining wet mass is called gum gluten which is dried and called vital gluten.

Gluten forming proteins: These proteins are classified into two major groups, viz. gliadins and glutenins, based on their extractability and unextractability, respectively, in aqueous alcohol.

Non-gluten forming proteins: Albumins and globulins are the non-gluten forming proteins. Albumins are water soluble and globulins are salt soluble proteins.

Gliadins proteins: These proteins are usually classified into four main sub-categories, α-, β-, γ- and ω-gliadins. These are soluble in aqueous alcohol. They are extensible proteins and are held responsible for viscosity or spread ability of dough.

Glutenin proteins: These proteins are the largest proteins among the proteins contained in wheat. They impart elasticity and strength characteristics to the dough.

1.9 SELF ASSESSMENT QUESTIONS

1. How Osborne and Shewry classification of wheat proteins differs?
2. Why gluten polypeptides are termed as prolamins?
3. What molecular and structural differences are there in gliadin and glutenin polypeptides?
4. Wheat gluten proteins have very low charge density. How this property of gluten proteins is important to end-use quality of bakery products?
5. What is the importance of total number and relative position of cysteine residues on the gluten polypeptides?

6. What effects will variations in flour protein content have on baked product quality?
7. How protein composition led to varietal variation in end-use quality of wheats?
8. High molecular weight glutenin polypeptides are quantitatively minor component of gluten proteins, but they are functionally important polypeptides of gluten. Justify this statement.
9. How glutenin subunits 5+10 act superior to subunit pair 2+12 in bread making?
10. Why strong flour is recommended for bread making and weak flour is recommended for biscuit making?
11. Discuss manufacturing techniques, uses and functionality of wheat gluten.
12. List major enzymes of wheat and explain their technological significance.

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PGDBST- 02 **B.S.Khatkar**

UNIT II: WHEAT LIPIDS & STARCH

STRUCTURE

2.0 OBJECTIVES

This unit provides information to the readers on important aspects of wheat starch and lipids. Roles of lipids and starch components in bakery products are discussed in this unit.

2.1 WHEAT LIPIDS

Lipids are classified as polar and non-polar lipids. Polar lipids interact with water and form aqueous phase, whereas non-polar lipids do not interact with water and do not form aqueous phase. Polar lipids in wheat originate from the cell membranes and are dominated by phospholipids and glyco- or galactolipids. Non-polar lipids are represented by triglycerides, and they are lipids at room temperature. Non-polar lipids can be extracted from wheat flour using chloroform. More polar solvents such as methanol extract the polar lipids. Wheat flour lipids constitute about 2% by weight of flour but make important contribution to dough properties, baking behaviour and bread staling. Some lipids in wheat remain bound to starch component and thus such lipids are called starch lipids, which comprise roughly one-fourth of the total lipid of a flour. They do not play any role in bakery products, although they may be important in staling of bread during storage.

2.1.1 EFFECTS OF LIPIDS ON RHEOLOGICAL PROPERTIES

Lipids interact with proteins of gluten complex and form large aggregates. The lipid-protein complexes contribute to the rheological properties of dough and gluten and thereby appear to contribute to the baking

quality of wheat flours. The flours extracted with lipids using organic solvents such as acetone-water mixture take longer time for dough formation and development as compared to the full fat flours. It has been noticed that lipids differ in their effects on dough properties made from strong and weak flours. The lipids tend to decrease the extensibility and extensigraph area of doughs made from strong flours. However, increasing lipids amount in weak flours tend to increase the resistance to extension and extensigraph area of dough. The non-polar lipids increase the mixing time of flour. The effects of nonpolar lipids on mixing times depend on the protein quantity and quality of the flours. The nonpolar lipids increase mixing time of strong flour more than that of a weak flour.

2.1.2 FUNCTIONALITY OF DEFATTED FLOURS

Lipids of wheat flour can be extracted with different solvents but efficiency of lipids extraction and effects of solvent on the functionality of the defatted flour govern the choice of solvent. Non-polar solvents such as petroleum ether generally do not cause adverse effect on the flour functionality but they fail to extract appreciable amounts of non-starch lipids. Alcohol-water mixtures efficiently extract the non-starch lipids but they tend to increase the mixing time of flours. Petroleum ether is generally preferred for defatting of flours as extract practically all the non-starch lipids and does not alter functional properties of flours.

Defatting improves following properties of flour:

1. Foaming properties
2. Flowability
3. Whiteness
4. Strength of dough

Defatted flour generally has stronger dough as indicated by rheological apparatus such as extensograph and alveograph.

2.1.3 ROLE OF WHEAT FLOUR LIPIDS FRACTIONS

Polar lipids improve baking quality of wheat flour. However, non-polar fractions are considered detrimental to the baking quality of flours. The polar lipids improve texture and loaf volume of bread substantially, making the bread softer and fresher. On the contrary, the non-polar lipids depress the loaf volume of bread making the bread compact and less acceptable by the consumer. The unsaturated fatty acids mainly linoleic, which constitutes more than half the free fatty acid in wheat flour, are held responsible for depression in the loaf volume and quality of bread. Among polar fractions, the glycolipids are more effective in improving quality of bread both in the presence and absence of shortening. Phospholipids do not contribute much to the quality of bread in the absence of shortening but they improve bread quality appreciably in combination with shortening.

2.1.4 LIPIDS AND BREAD MAKING POTENTIAL

The polar lipids improve bread making potential of a flour. By contrast, non-polar fractions depress the bread making quality of a wheat

flour. The polar lipids of 0.5 per cent exert same improving effect on bread quality, measured as loaf volume, as with 3 per cent of shortening. The decrease in loaf volume of bread by non-polar lipids is linked to the presence of free fatty acids in non-polar lipid fractions. Exchange of lipids between wheat varieties does not influence the bread making quality of flours.

The air that is beaten into dough during mixing acts as gas cells. During fermentation the gases produced by yeast activity are accommodated in these gas cells. The polar lipids play important role in stabilizing the gas cell structure due to their foaming properties. The polar lipids create a thin layer of foam on the interface of dough. This thin layer of foam is credited with stability of gas cells/bubbles. The involvement of polar lipids in gas cell stability is viewed as beneficial for bread quality. The glycolipids and phospholipids in association with surface-active proteins act as gas cell stabilizers while the non-polar lipid fractions act as gas cell breakers. Among the non-polar fractions, the presence of free fatty acids appears to correlate with gas cell instability and poor bread quality. The gas cell stability induced by lipids play more important role at the stage of oven baking. At this stage, the greatest stress is caused on the dough structure and any inherent weaknesses in flour dough are exposed. The flour dough lacking in polar lipids may develop large bubbles at early stage of oven baking and collapse due to instability of gas cells.

Lipids also play some role in retarding staling (texture hardening) of bread. It has been proposed that the lipids prevent firmness of breadcrumb by preventing retrogradation of starch molecules. The rigidity or reallocation of the retrograding starch network is mainly held responsible for bread firmness. The lipids are thought to remain concentrated around the surface of starch granules during baking and hence prevent or reduce contacts between gelatinized starch molecules.

2.1.5 EFFECTS OF LIPIDS ON BISCUIT, COOKIES AND CAKE QUALITY

The quality of biscuit or cookie is judged by surface characteristics, spread and top grain score as well as internal structure of the product. Cookies baked with lipid extracted flour causes spread and to grain score to be greatly reduced. It has also been observed that cookie spread and top grain score are improved as the lipids are added to flour up to four times the natural level. These effects may be due to the fact that the lipids have starch-binding action, and when such lipids are extracted from flour the starch gelatinization temperature is decreased and the gelatinization of starch takes place in the early stages of baking which prevents the spreading of cookies. Similar to bread, the polar glycolipids and phospholipids are found to be functionally beneficial in cookie also and the effects of these lipid fractions may be related to their contribution to gas cell stability.

Alike bread, the quality of cakes is assessed by their volume, internal texture, softness and freshness. However, cakes differ from bread and cookies in the sense that they are baked as batters (loose dough). Cake flour is generally treated with chlorine to bleach the flour and to enhance its baking potential. It is also agreed that chlorinating flour modifies functionality of lipids. The lipids play a role in foam production and stability of cake batter.

2.2 WHEAT STARCH

Starch is the major constituent of wheat flour. It represents 65-75 per cent of flour depending up on extraction rate. Starch is fixed in grain in the shape of special cells known as amyloplasts, and the starch particles are called granules. The starch granules provide nutrients and energy to seed during germination. The size of wheat starch granule ranges from 1-30 μm. The starch granules are classified as A- granules and B-granules. The composition of granules in wheat starch is listed in Table 2.1.

Table 2.1 Composition of granules in wheat starch.

Type of granule	Size	Average Diameter (μm)	% of starch	% total of number of granule
A-granule	Bigger	14	75	10
B-granule	Smaller	4	25	90

The proportion and size of granules are related to baking potential of flour. It is noted that large starch granules produce significantly higher loaf volume of bread than the small granules. However, there is an optimum

proportion of large and small granules, and this proportion appears to be close to one that is found in native flour.

The starch granules are composed of the polysaccharide amylose and amylopectin. Amylose is a linear polymer of glucose units linked by α (1→4) glucosidic linkages. Amylopectin is considered to be a branched glucose polymer having α (1→4) as well as a few per cent (4-5%) of α (1→6) glucosidic linkages. The proportion of amylose and amylopectin in wheat starch is generally found 30% and 70%, respectively.

Starch plays several important roles in bakery products. The summary of functions of starch in baking is illustrated in Table 2.2.

Table 2.2 Functions of starch in baking

1.	Starch provides yeast the fermentable sugars through action of amylases.
2.	It helps in setting the final texture of baked products.
3.	Dilutes gluten to desirable consistency
4.	Furnishes surface suitable for 'anti-sticky' proteins (friabilins) that affects hardness of grains.
5.	Furnishes surface suitable for starch-protein interactions that contributes to stability of gas cells in bread baking.

The pasting or gelatinization behaviour of starch is considered important in bakery products. Gelatinization of starch refers to a term that describes several changes in the starch at different temperature encountered

in the baking operations. The process of gelatinization of starch involves following steps or changes in starch granules:

- absorption of water by starch granules and its swelling
- change of shape and size of starch granules
- leaching of amylose or amylopectin from granules
- formation of a gel or a paste due to increase in viscosity of the system
- setting of the texture of bakery products during baking.

The starch has also been shown to affect the cookie or biscuit quality. Gelatinization of starch during baking plays important role in producing internal texture of cookie. Starch also contributes to the crust colour formation of biscuits and cookies. At temperature above 180°C, the starch begins to get converted into dextrin that undergo caramelization and thus, contributes to the crust colour of bakery products with sugar rich formulation. Increasing starch content in wheat flour increases the diameter and spread factor of cookies. This may be due to the dilution of gluten by increase in level of starch in the dough. Lesser amount or dilution of gluten improves the extensibility and spread of dough during baking.

2.2.1 ROLE OF DAMAGED STARCH IN BAKERY PRODUCTS

Damaged starch is one that has been physically damaged during the wheat milling process. The starch granule gets physically altered during milling and it is referred to as ‘damaged’. The percentage of starch damage

differs between flours milled from different wheat varieties. Milling of a hard variety requires more energy and thus severity of grinding results in higher percentage of damaged starch in hard wheat flours. By contrast, lesser energy is needed to grind soft wheat grains to desired particle size flour and hence the soft wheat flour generally has lesser percentage of damaged starch. Mechanical injury to the starch granule makes it more susceptible to enzyme action. A wheat flour having higher proportion of damaged starch will also have higher amylolytic or diastatic activity. The diastatic activity is the capacity of flour to produce fermentable sugars, i.e. its amylolytic activity.

Diastatic activity of a flour is expressed as milligrams of maltose produced/10 g of flour/hr at 30 °C. Higher value indicate higher diastatic activity. The desired level of maltose value is between 2.5 to 3.5 mg/10 g flour. Lesser value will cause poor gas production capacity of a flour, whereas higher value may lead to production of excess gas during fermentation of dough and the dough may collapse in early stages of baking due to excessive internal gas pressure. Therefore, the proportion of damaged starch in a flour is of great importance to the rheological and baking quality of the flour. The starch damage is held largely responsible for differences in water absorption, dough handling properties, sugar and gas production during fermentation of a dough. The water holding capacity of damaged starch increases four times of the normal starch. The water holding capacity of

normal starch is reported to be 0.44 g water/g of dry starch, while damaged starch can hold as much as 2.0 g water/g of dry starch.

Desired level of damaged starch for bread production is 7-9%. Excessive starch damage can create problems in dough handling and can also depress loaf volume and slicing of bread loaf also becomes difficult. For cookie and biscuit making, damaged starch should be < 7%, as higher per cent of starch damage makes the starch more susceptible to enzyme attack that results in smaller cookies.

2.2.2 STARCH AND BREAD STALING

Starch plays a significant role in bread during storage when the aging or staling begins. Bread staling refers to firming or hardening of bread during storage that decreases consumer acceptance of bread. The starch causes bread staling due to its retrogradation or re-association of starch fractions i.e. amylose and amylopectin after baking and during storage. Retrogradation of starch contributes to hardening of breadcrumb during storage. Retrogradation of starch in breadcrumb is said to be water, time and temperature dependent. Staling rate of bread is recorded maximum at 4°C. The bread hardness is lesser at higher temperature. Redistribution of water is the key factor for retrogradation of starch in bread. The water level of 20 to 30 per cent is required for retrogradation of starch to occur. The moisture content in bread is found in the range of 40%. Therefore, starch retrogradation in bread occurs readily at such levels of moisture. Water aids in mobility or recrystalization

of starch fractions. Starch retrogradation changes A-pattern of native starch to B-pattern. The water holding capacity of B-pattern of starch is poor and hence the breadcrumb looses water and becomes harder. This process is reversible and hence the freshness of bread can be resumed on heating the bread above temperature of 45°C. This again changes the starch from B-pattern to A-pattern and freshness is restored as A-pattern of starch can hold more water.

2.3 SUMMARY

Wheat flour lipids constitute about 2% by weight of flour but make important contribution to dough properties, baking behavior and bread staling. Some lipids in wheat remain bound to starch component and thus such lipids are called starch lipids, which comprise roughly one-fourth of the total lipid of flour. They do not play any role in bakery products, although they may be important in staling of bread during storage. Lipids are classified as polar and non-polar lipids. Polar lipids interact with water and form aqueous phase, whereas non-polar lipids do not interact with water and do not form aqueous phase. Polar lipids in wheat originate from the cell membranes and are dominated by phospholipids and glyco- or galactolipids. Non-polar lipids are represented by triglycerides, and they are lipids at room temperature. Non-polar lipids can be extracted from wheat flour using chloroform.

Starch is the major constituent of wheat flour. It represents 65-75 per cent of flour depending up on extraction rate. Starch is fixed in grain in the shape of special cells known as amyloplasts, and the starch particles are called granules. The starch granules are classified as A- granules and B-granules. The proportion and size of granules are related to baking potential of flour. It is noted that large starch granules produce significantly higher loaf volume of bread than the small granules. However, there are an optimum proportion of large and small granules, and this proportion appears to be close to one that is found in native flour. The starch granules are composed of the polysaccharide amylose and amylopectin. Amylose is a linear polymer of glucose units linked by α (1$\rightarrow$4) glucosidic linkages. Amylopectin is considered to be a branched glucose polymer having α (1$\rightarrow$4) as well as a few per cent (4-5%) of α (1$\rightarrow$6) glucosidic linkages. The proportion of amylose and amylopectin in wheat starch is generally found 30% and 70%, respectively.

2.4 KEY WORDS

Polar lipids: Lipids those interact with water and form aqueous phase are termed as polar lipids.

Non-polar lipids: Lipids which do not interact with water and do not form aqueous phase are called non-polar lipids.

Amylose: It is a linear polymer of glucose units in starch linked by α (1$\rightarrow$4) glucosidic linkages.

Amylopectin: It is considered to be a branched glucose polymer of starch having α (1$\rightarrow$4) as well as a few per cent (4-5%) of α (1$\rightarrow$6) glucosidic linkages.

Damaged starch: It is the starch that has been physically damaged during the wheat milling process. The starch granule gets physically altered during milling and it is referred to as 'damaged'.

Diastatic activity: It is expressed as milligrams of maltose produced/10 g of flour/hr at 30 °C. Higher value indicate higher diastatic activity. The desired level of maltose value is between 2.5 to 3.5 mg/10 g flour.

Bread staling: It is the firming or hardening of bread during storage that decreases consumer acceptance of bread.

2.5 SELF ASSESSMENT QUESTIONS

1. Give a brief account of classification and composition of wheat lipids.
2. Explain the contribution and role of wheat lipids in rheological properties of dough.
3. Why all organic solvents are not recommended for extraction of wheat lipids?
4. Explain functionality of defatted flour.
5. Polar lipids play positive role, while non-polar fractions depress bread quality. Explain how?
6. Discuss the effects of lipids on biscuits, cookies and cake quality.

7. How wheat flour starch granules get damaged? How damaged starch differs from native starch?
8. Discuss the functions of damaged starch in bread making.
9. How does damaged starch affect the quality of soft wheat products?
10. In what way damaged starch is related to staling of bread.

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PGDBST- 02 **B.S.Khatkar**

UNIT III: FUNCTIONALITY OF MAJOR INGREDIENTS

STRUCTURE

3.0 OBJECTIVES

Thorough study of this unit will enable the reader to understand:

- Role of water in the formation and processing of bread, biscuit and cookie dough
- Contribution of water during processing, baking, cooling and freezing of dough
- Effects of water on bakery products texture properties
- Baker's yeast – production & properties
- Functionality of salt, sugars and shortening in bakery products

3.1 ROLE OF WATER IN THE FORMATION AND PROCESSING OF WHEAT BREAD, BISCUIT AND COOKIE DOUGH

The water content of flour dough depends up on its end use. Bread dough generally contains 65% water on flour weight basis. The water requirement of flour for biscuit and cookie dough is significantly lower and sometime dough is prepared without water for certain biscuits. Bread quality is more sensitive to water content in dough. The loaf volume is less with lower water content in dough. The optimum level of water addition is related to the composition of the flour. The water absorption capacity of flour depends on the following factors:

1. Moisture content: the drier flour will have higher water absorption capacity.

2. Protein content: flour with higher protein content will absorb more water.

3. Damaged starch: higher level of damaged starch in flour increases its water absorption capacity. Intact starch can absorb 0.40 g water /g dry starch, but damaged starch absorbs 2 g water/g dry damaged starch.

4. Pentosan content: the higher the pentosan level, the higher the water absorption capacity of a flour. One gram of pentosan can absorb 5-gram water.

5. Enzymatic activity: the greater the enzymatic activity, the lower the water absorption capacity of flour.

The process of dough formation begins with hydration of the flour particles in a mixer. The mixing, whilst the flour is hydrating, brings about development of the gluten network, which is evidenced as an ascending part of the mixing curve. The dough system subsequently becomes more coherent, losing its wet and lumpy appearance, and the height of the curve gradually increases to a peak, i.e. a point of maximum consistency or minimum mobility. This is the point to which a dough should be mixed for producing a bread of superior loaf quality. If mixing is continued beyond this point, mechanical degradation of the dough occurs resulting in the curve sloping downward and tailing off. Eventually the dough becomes wet, sticky and extremely extensible, and is capable of being drawn out into long strands. This is generally referred to as the dough being ‘broken down’. Such dough is sticky, difficult to handle and more extensible.

The water plays similar role to fermented dough in the production of biscuit and cookie, with respect to dispersion and hydration of ingredients. In biscuit dough water requirement is low because limited gluten development is needed so that changes in biscuit shape i.e. shrinkage after forming and during baking are minimised. Hard dough semi-sweet biscuits require some

gluten development and thus water requirement tend to be slightly higher up to 20-25% on flour weight basis.

3.2 CONTRIBUTION OF WATER DURING PROCESSING, BAKING, COOLING AND FREEZING OF DOUGH

Water plays remarkable role in fermented and non-fermented bakery products. Water influences the wheat and wheat products from the point of its storage to its final processed products. Wheat grains should be stored at moisture content below 14% for stability during storage. Wheat grains are tempered by adding water in order to make the bran tough and leathery and to make endosperm soft and mellow. The tempering process facilitates clean separation of bran from endosperm and also helps in further grinding of endosperm chunks into flour with desirable particle size. Mixing ingredient in the presence of water can process wheat flour further.

Water is required for gluten formation, cohesiveness of dough and it acts as medium for all types of interactions and biological reactions that occur during processing of a dough into a bakery product. Carbon dioxide produced by yeast during fermentation is dissolved in to the water present in dough phase. The same carbon dioxide later expands and gives rise to porous texture to the fermented bakery products. During baking the key transformations such as gelatinisation of starch and coagulation of gluten involve movement of water within dough system. In oven the starch granules starts to swell at around 45°C and gelatinisation begins at around 60°C. Gelatinisation of starch involves a change from an ordered, crystalline state to disordered amorphous state of starch granule. Starch granules need more water for this transition, which it takes from gluten network. Heating dough beyond the starch gelatinisation/gluten coagulation temperatures involve continued loss of water.

At advance stages of baking the foam structure of dough get converted into sponge structure with desired sponginess or bite characteristics of bread and cake like products. In biscuit types of product, the baking leads to coagulation of protein and setting of texture by starch. As the water is removed during baking to a level less than 5% in these products the crispness of products is achieved.

Freezing is practised in many bakery applications in order to retain organoleptic properties of product for extended period of time. As the temperature in the product falls below 0°C, the water present in product begins to freeze and ice crystal forms. The dough is prepared in bulk in large bakeries and it is kept in frozen state. The required quantity of dough is thawed and utilised as and when it is required.

3.3 EFFECTS OF WATER ON BAKERY PRODUCTS TEXTURE PROPERTIES

Water in baked products plays a crucial role in the organoleptic or eating quality. Bread and other fermented baked products have high moisture contents i.e. in the range of 40 per cent. The moisture contents of these products indicate freshness. The higher the moisture contents, the more fresher will be the bread and vice-versa. Higher moisture contents make the bread soft. Such bread will also have better chewiness and consumer satisfaction. Loss of moisture content during storage is the primary reason of staling of bread. Moisture loss in bread makes the crust leathery and crumb looses its freshness.

The moisture contents of freshly baked biscuits and cookies are usually below 5 per cent. At this moisture contents these products are crispy and tasty. As the moisture content increases, the products lose their crispness and become soggy and less acceptable to the consumers. Higher moisture

contents also spoil the taste these products due to rancidity developments, as they are rich in fat contents.

3.4 BAKER'S YEAST – PRODUCTION & PROPERTIES

Baker's yeast (*Sacharomyces cerevisiae)* is primarily used in the bakery industry because it is produced commercially in large quantities and has ability to produce large volume of gas in dough system. India produces about 10,000 tonnes of baker's yeast per annum as compared to a total world production of 1.8 million tonnes per annum. The growth in demand of yeast is reported to be 12% per year. Two types of baker's yeast are produced commercially, namely wet compressed yeast (WCY) and active dry yeast (ADY). Economically developed countries also produce another form of baker's yeast called instant yeast (IDY). It is dry and porous and hence can be mixed with flour without any need for dispersion in water as is required in the case of WCY and ADY. Generally about 1.0% of ADY or 4.0% WCY (flour basis) is used while mixing dough for manufacture of bread. The functions of baker's yeast are:

1. to produce required volume of gas
2. to impart desirable flavour and aroma and
3. to develop spongy texture of fermented products

3.4.1 YEAST PRODUCTION

The organised production of baker's yeast from grains was originated in Central Europe in 19th Century. Later on several advances such as use of aeration, centrifugation for recovery of yeast, introduction of pure cultures, incremental feeding and replacement of grain mashes with cheaper molasses

were achieved. Different systems of fermentation such as batch, fed-batch and continuous are used for commercial production of yeast. Out of these, fed batch fermentation is commonly used in industries with yeast concentration up to 4.5% (dry weight basis).

Basic principles of yeast production

The following basic principles are involved in the production of baker's yeast.

1. The sugar must be fed to the yeast in increment rate (fed-batch) so that no sugar is detectable at any given time of fermentation. This will ensure maximum yeast biomass provided aeration is efficient.

2. Enough oxygen must be supplied (1g O_2/g biomass) by injecting sterile air so as to maintain a positive pressure of oxygen in the medium.

3. The heat liberated during growth cycle of yeast (3.7 kcal/g of yeast) must be withdrawn by cooling at a temperature of 28-30°C in order to obtain maximum yields.

4. Antifoaming such as silicone and fatty acid derivative agents should be used to avoid foaming.

5. The pH should be maintained 3.5 to 4.5 to avoid bacterial contamination.

6. Yeast should be provided with nitrogen, phosphorous and vitamins for maximum yield.

Manufacturing process

It is produced in 5-8 stages starting from a slant culture to a commercial stainless steel fermentor of 200 m^3, which is provided with all accessories for feeding of molasses, nutrients, aeration, agitation, pH, an antifoam control as well as an automatic process control device. After the fermentation is carried out for a period of 13 to 16 hr by appropriate feeding of nutrients and oxygen, the yeast cells are harvested by yeast separators to obtain yeast cream, which is then passed through a plate-and-frame filter press to get yeast cake. The cake is mixed with an anti-oxidant like butylated hydroxy anisole (BHA) to a level of 0.1% and emulsifier like sorbitol ester at 1.0% on dry weight basis of yeast, extruded into blocks of 0.5 to 1.0 kg, wrapped in wax paper and stored at 4°C for 4-5 weeks. It is also transported to places of use under refrigerated conditions.

The above protected wet yeast is extruded into a form of noodles or strands and dried in fluidised bed drier at 45°C for 4-5 hr to get granules of 0.5 to 3 mm diameter. These are packed in cans under the atmosphere of N_2 gas and stored under ambient conditions.

Storage Stability

Storage stability is an important criterion for the quality of baker's yeast. The WCY contains usually 68-75% moisture and as such perishable product requiring cold storage. The stability of this yeast is inversely proportional to the storage temperature. High reserve carbohydrates like trehalose and storage under anaerobic conditions prolong the shelf life of yeast. It can be stored at 4°C satisfactorily over a period of 3-4 weeks.

Since ADY contains less than 10% moisture, its stability is significantly better than WCY. It varies from 2 to 12 months depending upon

its storage temperature and atmosphere as well as nitrogen and moisture contents. Addition of anti-oxidants like BHA and storage under N_2 gas improves the shelf life of ADY. Because of these properties, ADY could be used even in rural areas, where the refrigeration facilities are lacking.

Properties

The yeast (*S. cervisiae var ellipsoides*) is generally regarded as safe (GRAS) and indeed possesses flavourable nutritional properties apart from being a leavening agent in dough by the production of CO_2. The yeast is rich in protein and B-complex vitamins as well as flavour compounds that would add on to the nutritional quality of bread.

Quality Parameters and Assessment

The general requirements are that the WCY should have a creamy white colour and odour characteristic of good baker's yeast and a fine even structure. It should not be slimy, moldy, no signs of deterioration and should be free from starch adulteration and other extraneous matter. ADY should be in the form of granules, pellets or flakes and other characteristics similar to WCY, except that edible starch up to 10% of biomass may be added as per Indian standards. Different parameters such as fermenting power of yeast, dough raising capacity, dispensability in water, moisture content and microflora other than yeast have been used to assess the quality of WCY and ADY.

3.4.2 FUNCTIONS OF YEAST

The primary function of yeast is to leaven the dough or to make it rise-and to produce a porous product. This is achieved by the production of carbon dioxide by yeast during fermentation operation in the fermented products. The yeast ferments sugar, producing carbon dioxide and ethanol.

The gas-producing power of the yeast is influenced by temperature, pH, alcohol concentration, nature of carbohydrate supply, osmotic pressure and yeast concentration. The optimum pH for gas production by the yeast is 5.5, but the yeast is quite tolerant to changes in pH, and the gas production is 80% of the optimum value in the pH ranges 3.7-8.0.

Besides contribution to bread loaf volume by production of CO_2, the role of yeast fermentation is to influence the texture of the dough, to contribute to flavor and aroma, and finally to enhance the nutritional value of the bread. The nutritional effect of yeast linked to the phytase activity of the yeast, which improves mineral uptake in the intestines. An alternative is to add phytase directly to the flour. Phytate in the dough will decrease the uptake of minerals due to complexing.

3.5 FUNCTIONS OF SALT

Salt an essential ingredient for most baked foods performs functions in baking that cannot be duplicated by any other ingredients. The ordinary granulated salt being relatively slow dissolving and contains higher levels of impurities (Copper, Iron & other metals), increases mixing time and accelerates gluten formation and hence toughen the dough through a direct action on the dough proteins or due to an inhibitory action on proteolytic enzymes and hence it is suitable for bread making. In contrast fine flake salt (99.95% purity of NaCl) with nine times faster solubility than that of ordinary salt and lesser tightening effect on the dough is preferred in cookie and biscuit preparation.

Not only salt imparts a flavour that makes the taste of a product good, but it also acts to accentuate the flavour of other major and minor ingredients for example, sweetness of sugar is emphasized by the contrasting taste of salt.

3.6 FUNCTIONS OF SWEETENERS

Sweeteners are regarded as the most important class of ingredients in bakery products. Some unusual varieties can be prepared without flour, a few without water (as such), and number without added leaveners, but no cookie/biscuit formula is possible without some form of sweeteners.

The primary purpose of sweetening agent is to make product sweet. The quantity of sweetening agent added is usually such that it has significant effect on the texture and appearance of the product as well as on favor. Machining properties closely related to the dough piece to oven conditions are also closely related to the type and quantity of sweetening agent employed.

The sweetening agents used in bakery products and in particular cookie/biscuit making has varied functions and may be divided into three categories:

1. Sucrose and invert sugar

2. Derivatives of cornstarch

3. Other sweeteners.

1. Sucrose and invert sugar

In bakery products formation the function of sucrose is not only as a nutritive sweetener, but also as texturiser, colouring agent and as a means of controlling spread. The sugars act as tenderizer by competing with flour components (gluten proteins) in the absorption of water and thus preventing the formation of firm gluten network. The optimum performance of the sugar is obtained by using particle size of sugar with a mean size range of 200 to

250μ. Cookie spread and top grain scores increase with decreasing mean particle size of sugar. Sugar with finer particle size gives greater spread.

This effect is due to the fact that finer particle sizes dissolve more rapidly than coarser particles. The higher sugar level (above 50% sugar on flour basis) gives greater spread than lower sugar level because higher sugar provide more dissolved sugar than lower sugar levels which competes successfully with starch and protein for water and decreases dough resistance to expansion during backing. Sugars increase the starch gelatinization temperature by binding starch, which helps in spreading of cookies during backing. All in one mixing give greater spread than mixing which included creaming because creaming of fat and sugar coats the sugar particles with fat and retards efficient dissolving of sugar.

Sucrose has the valuable property of retarding microbiological spoilage when it is present in high concentrations. Cookie/biscuit maker prefers to use some amount of invert sugar in some cookie formulae, as it assists in retaining moisture and promotes chewiness. Invert sugar also contributes to a richer, more appealing crust, colour, as it caramelizes more readily. Invert sugar is prepared by heating a solution of sucrose in the presence of traces of strong acid or by enzymatic reaction (invertase). The invert syrups are, generally sweeter than sucrose alone.

Brown sugar, containing 2 to 3 percent of residual invert sugar, does not promote spread equal to regular granulated sugar. The brown sugar syrup contributes a characteristic colour and flavor which is considered desirable in many kinds of cookies.

2. Derivatives of corn starch

Corn sugar is approximately two-third as sweet as sucrose; therefore, additional quantities of corn sugar are necessary to obtain comparable sweetness. Corn sweeteners contain both dextrose and fructose which readily participate in the classic non-enzymatic browning scheme involving formation of hexose-amines and their subsequent rearrangements to high molecular weight pigment (melanoides) and hence impart good crust colour in the baked cookies. Corn sweeteners are economically also.

3. Other sweeteners

Honey is natural syrup, rich in fructose and mainly used in cookies for development of specific flavor, crust colour and additional softness. They also increase the nutritional value of bakery products. In most cookie applications use of saccharin, a synthetic sweetener is to replace sugar in dietetic formulations. Saccharin is about 300 to 500 times sweeter than the table sugar.

3.7 FUNCTIONS OF FAT/SHORTENING

Any edible fat used in bakery products is known as shortening. Shortening is essential components of most bakery products. The amount of shortening in the formula influences both the machining response of the dough and the quality of the finished products. The saturated fatty acids are more important than unsaturated fatty acids as shortening because the saturated fatty acids are chemically complete and stable and therefore, do not undergo much bio-chemical when stored.

1. Properties of shortenings

Shortenings should have a plastic nature over a wide range of temperature. Temperature plays an important role in the distribution of fat. If the temperature rise is higher than the maximum of the shortenings plastic range, then liquid oil will result, causing oily dough while low temperatures tend to cause hardening of the shortening, causing uneven distribution in dough.

The plasticity of shortening while mixing dough encourages the entrapment and retention of considerable quantities of air and thus contributes to the texture of the baked products. Shortening, super cooled badly, having large crystal structure gives dough with poor moulding potential and variable product weights and dimensions.

Hydrogenated oils with their mono-diglyceride fractions encourage not only emulsification but also the homogeneous distribution of the fat soluble and emulsified ingredients throughout the dough and hence contribute to tenderness in product.

During hydrogenation process, hydrogen is added directly to the points of unsaturation in the fatty acids to convert the oils into solid fats, by which the stability of fat is increased to oxidative rancidity.

The “off flavour” developed in bakery products during an extended shelf life is due to rancidity developed in the shortenings. These are mainly due to:

(a). Breakdown of fatty acid chains by oxidation,

(b). Spoilage by micro-organisms,

(c). Fat splitting by enzymes, particularly lipase and

(d). Absorption of foreign odours.

2. Functions of fat/shortenings

(a). Shortening reduces the toughness of dough.

As gluten does not form until the flour is in contact with water and mixing action, the inclusion of fat tends to insulate and the gluten forming proteins from the water and consequently, a less tough dough results which is rather more extensible and ideally suited for cookie making. The greater the amount of fat, the greater will be the insulating effect. Excessive mixing will breakdown the insulation and a tough dough will result again.

(b). It improves dough for machining and sheeting by lubricating the gluten.

(c). Controls the flow of dough

(d). Gives shorter bite to the goods

(e). Enhances the product flavour and taste

3. Types of shortenings used

Some of the commonly used shortenings are summarized below.

(a). Hydrogenated vegetable fat (Vanaspati): Hydrogenated vegetable fats (Vanaspati) are universally used because these are economical as compared to animal fats. Butter, coconut oil, and palm kernel oil, all of which contain a high proportion of short-chain fatty acids (for example, lauric acid in coconut oil), have much lower shortening values than domestic vegetable

shortening such as hydrogenated soybean or cottonseed oils. Therefore, hydrogenated soybean or cottonseed shortenings are widely used. Coconut oil is used in bakery industry as a spray fat, fillings and coatings. Crude vegetable oils are not used directly in the bakery products because of the presence of impurities.

(b). Butter: Butter has specific flavour, which makes a significant contribution to the acceptability. It has certain organoleptic attractions for the consumer. Ripened butter of extremely high flavour is widely used. However, the relative low-melting point of butter fat leads to occurrence of greasiness in the products. This greasiness causes annoyance during handling and tends to smear packing material. The butter also causes early development of rancidity and it is expensive also.

(c). Margarine: Margarine has taken place of butter in most bakeries today because of its wide range of properties. The consistency of the fat portion can be adjusted to minimize the greasiness normally found in baked goods containing butter, it can also be blended with softer fats, the margarine may or may not be coloured and can be flavoured to varying intensities. Lecithin and monoglycerides can also be included in it.

(**d). Lard**: Lard is used in vast quantities in western countries since it has a distinct and desirable natural flavour. But in India its use is limited due to religious factors. Straight refined lard with added anti-oxidant is generally used.

3.8 SUMMARY

Bakery products are greatly influenced by the formula ingredients such as water, flour, fat, sugars, salt, yeast, etc. The water content of flour dough depends up on its end use. Bread dough generally contains 65% water on flour weight basis. The

water requirement of flour for biscuit and cookie dough is significantly lower and sometime dough is prepared without water for certain biscuits. Bread quality is more sensitive to water content in dough. The loaf volume is less with lower water content in dough. The optimum level of water addition is related to the composition of the flour. Water plays remarkable role in fermented and non-fermented bakery products. Water influences the wheat and wheat products from the point of its storage to its final processed products.

The primary function of yeast is to leaven the dough or to make it rise-and to produce a porous product. This is achieved by the production of carbon dioxide by yeast during fermentation operation in the fermented products. The yeast ferments sugar, producing carbon dioxide and ethanol. The gas-producing power of the yeast is influenced by temperature, pH, alcohol concentration, nature of carbohydrate supply, osmotic pressure and yeast concentration. Salt an essential ingredient for most baked foods performs functions in baking that cannot be duplicated by any other ingredients. Not only salt imparts a flavor that makes the taste of a product good, but it also acts to accentuate the flavor of other major and minor ingredients for example, sweetness of sugar is emphasized by the contrasting taste of salt. The primary purpose of sweetening agent is to make product sweet. The quantity of sweetening agent added is usually such that it has significant effect on the texture and appearance of the product as well as on flavour. Shortening is essential components of most bakery products. The amount of shortening in the formula influences both the machining response of the dough and the quality of the finished products.

3.9 KEY WORDS

Water absorption capacity of flour: Wheat flour absorbs certain amount of water to form dough suitable for processing into a bakery product. This amount of

water absorption by flour is referred to be water absorption capacity of flour. It depends upon the protein, pentosan, damage starch and enzyme contents of flour.

Shortening: Any edible fat used in bakery products is known as shortening.

Baker's yeast: The yeast *Sacharomyces cerevisiae* is known as baker's yeast as it is primarily used in the bakery industry because it is produced commercially in large quantities and has ability to produce large volume of gas in dough system.

Damaged starch: It is the starch that has been physically damaged during the wheat milling process. The starch granule gets physically altered during milling and it is referred to as 'damaged'.

3.10 SELF ASSESSMENT QUESTIONS

1. Describe the role of water in the formation of dough for processing it into bread, biscuits and cookie.
2. Indicate the factors affecting water absorption capacity of flour.
3. How water contributes in processing and freezing of dough?
4. Explain the role of water in influencing the textural properties of bakery products.
5. Discuss production, properties and functions of yeast in fermented bakery products.
6. Discuss the functions of salt and sweetening agents in bakery products.

7. Classify fat/shortening used in bakery applications and describe its role in bakery products.

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PGDBST- 02 **B.S.Khatkar**

UNIT IV: FUNCTIONALITY OF MINOR INGREDIENTS

STRUCTURE

4.0 OBJECTIVES

This unit provides information to the readers about the properties and role of minor ingredients such as milk and milk products, malt and malt products, oxidizing and reducing agents, yeast foods, surfactants and anti-microbial agents in influencing the processing and quality of bakery products.

4.1 INTRODUCTION

In most baking formulation, the wheat flour is the predominant ingredient. Other ingredients such as yeast, sugar, shortening, milk and milk products, malt and malt products, yeast food, oxidizing and reducing agents, surfactants and anti-microbial agents also contribute towards the improvement of finished bakery product. All these ingredients play specific role in bakery products. The optional ingredients are also added in the formulation to create variety in the products. The functionality of each of these ingredients in bakery products is explained in the following paragraphs.

4.2 MILK AND MILK PRODUCTS

4.2.2 GENERAL FUNCTIONS

Milk and milk are traditional components of bakery items and they are used for their several desired functions.

1. Milk and milk products impart a high moisture absorption capacity to dough, causing an increase in dough handling during processing.
2. Increase buffering capacity during fermentation and thereby prevent rapid and excessive acidification.
3. Facilitate better control of amylase activity.
4. Improve tolerance to bromate.

5. Facilitate moisture transfer during gelatin of starch.

6. Minimize the effects of over mixing.

7. Enhance flavour development and crust colour formation.

8. Improve toasting characteristics.

9. Strengthen crumb structure and texture.

10. Improve moisture relation and retard staling process.

11. Enhance nutritional value. The protein efficiency ratio (PER) of bakery goods is significantly improved when milk products are used in the formula. The reason for this nutritional improvement is that wheat flour protein is deficient in lysine and tryptophane, both being essential amino acids. Addition of milk products helps overcome this deficiency and improves the quality of protein in the finished products and the products become more efficient in supplying the daily needs of the body protein.

4.3 TYPES OF MILK AND MILK PRODUCTS

There are several types of milk and milk products that are available to a baker. These can be classified into three general groups, namely, (1) fresh liquid milk (2) concentrated milk products and (3) milk powders. In the category of fresh products, the liquid whole milk, non-fat milk (skim), and buttermilk are included. Concentrated products may include condensed whole milk, condensed skim milk, buttermilk and sweetened condensed whole milk. The dry products include dry whole milk, non-fat dry milk solids, butter and whey powder. These vary in moisture, butterfat, milk sugar (lactose), protein and ash content. They, therefore, function differently when used in bakery products.

4.3.1 ROLE OF FRESH MILK

Milk when used in bakery products, draws our attention to two aspects- (1) water in milk and (2) total solid contents in milk. The water component in liquid milk could range between 80 to 90% depending on the type of milk. The water present in milk contributes towards eating qualities. The moisture of milk when combined with other ingredients may contribute to both toughness and tenderness in the products. The milk solids have a binding effect on the flour protein creating a toughening effect. Milk contains lactose that improves digestion since it has ability to promote the growth of certain desirable lactic acid producing bacteria in the intestine. The lactic acid is thought to promote absorption of calcium and phosphorus needed for bone formation. Milk solids also improve flavour, nutritional value of bakery products and are important moisture retaining agents and hence retard staling process in bread.

4.3.2 ROLE OF NFDM (NON-FAT DRY MILK)

NFDM solids perform a variety of functions in bakery products, which are discussed in the following paragraphs.

1. Increase absorption and dough strengthening:

NFDM solids appear to act as strengthening agents to flour proteins resulting in an increased loaf volume, particularly when flour of medium strength is used. For weak flour larger quantities of milk are recommended. Good quality milk solids can carry 100 to 125% of their weight in waters compared to 58 to 64% carried by most wheat flours. This ability of moisture retention of NFDM improves freshness of bread during storage.

2. Improve crust colour:

The lactose, casein and whey proteins in NFDM solids contribute to a golden crust colour and also improve toasting qualities. Lactose (milk sugar)

is not fermented by baker's yeast so it is available in the oven to react with proteins to enhance the colour of the crust. This also helps in browning the toast evenly.

3. Improve tenderizing and toughening effect:

Lactose, lactalbumin and lactglobulin together with the minor soluble proteins have a tenderizing effect on crumb structure. Casein, which comprises about 75% of the total proteins in NFDM solids, is a dough toughener, which helps in putting body and resilience into the crumb of the sliced bread.

4. Better nutrition:

Bakery products with milk solids are nutritionally better because they contain more minerals, proteins and vitamins. Casein, lactabumin and lactglobulin fraction of milk proteins is higher in biological value than wheat proteins. They are also good source of lysine and tryptophane amino acids, both of which are deficient in wheat proteins.

Whole dry milk (WDM) can replace NFDM in pastries and pie fillings because it contributes a rich appetizing flavour and improves the texture by virtue of extra fat present in it.

Sweet whey powder (SWP) is reported superior to NFDM in cookies and pretzels, because of absence of casein, it does not possess the same humectant properties as NFDL and its higher lactose content produces a better surface colour and taste. For food products in which low water retention is desired. SWP is preferred e.g. biscuits and cookies. In cookies, NFDM solids have been reported to improve spread ratio, crust colour, flavour, eating qualities and nutritional value.

4.3.3 WHEY PRODUCTS

Whey products are assuming major interests for bakers and other food formulations for two reasons; first, the increased emphasis on whey utilization coupled with recent technological advances and secondly, the continuing rise in NFDM prices. Whey is thus a logical alternative to NFDM. It provides the same crust colour, flavour and aroma as that is imparted by MFDM.

Definition of whey

Whey is a co-product of the cheese making process. It is milk that has undergone a coagulation process through which the casein proteins and milk fat are removed as cheese curd. Sweet whey is the co product of rennet - coagulated cheese such as cheddar and Swiss. Acid cheese whey is the co-product of acid coagulated fresh cheese, principally cottage.

Role of whey and whey components

1. Softness/tenderness:

Use of whey in bakery products results in softer cakes, biscuits, breads, cookies, pie crusts and rolls. The unique water blinding properties of lactose and whey proteins contributes the softness or tenderness. Whey proteins and lactose also facilitate emulsification of shortening.

2. **Loaf volume:**

The usage of whey in bread reduces the loaf volume. This problem can be resolved by giving high heat treatment to whey resulting in denaturation of protein components that contribute to lower loaf volume. Whey proteins (4 to 6% flour weight) have been added to doughs containing 0.5% sodium stearoyl -2-lactylate without loss in loaf volume or quality score.

3. **Crust colour:**

Whey proteins and lactose impart golden brown crust to bakery products through Maillard reaction. Whey contains sufficient quantities of free amino groups to interact with the lactose. In contrast, flour proteins, although present to a far greater extent in a dough system do not greatly enhance crust colour.

4. **Flour and Aroma:**

Many flavour and aroma components are developed during baking results from the thermal degradation of proteins and amino acids. The degradation of these amino acids are associated with definite aroma: leucine, bread like (toasted): proline, bakery or cracker; glutamine and lysine, buttery; leucine, orginine and histidine, bread like.

5. Role in Cakes:

Whey is added with cascinates or other protein sources to provide grain, volume, colour and flavour in cakes. In cake mixes and topping formulation, the presence of lactalbumin is desirable since this protein has good whipping properties.

6. **Role in Cookies:**

Whey improves flavour, aroma, colour and nutritive value of cookies. It aids in producing easily machined dough for high-speed production with die cut process.

7. **Role in pie crust**:

Whey contributes a rich appetizing flavour and colour in pie crusts. It permits the reduction of shortening without sacrificing tenderness and flakiness.

8. **Role in white bread**:

Whey products improve colour, flavour and aroma of white bread. No appreciable effects are reported on dough properties when whey is used at 2 to 8% (flour basis). Bread quality is deteriorated by increasing the levels of whey in formula from 2 to 8%. Partial demineralization of whey improves the performance in bread. Acid whey weakens the dough structure and produces firmer breadcrumb than sweet whey.

Improvement in bread quality is noticed when high heat treated (70^0C for 30^0C) whey is used in dough. Increase in amount of whey increases loaf volume but decreases other internal and external characteristics of bread. Breads with added whey is found fresh than the control over a period of storage.

4.3.4 ROLE OF BUTTER MILK POWDER (BMP)

The presence of appreciable quantities of volatile fatty acids and phospholipids in BMP renders it an ideal ingredient for butter and cake mixes because of its emulsifying properties. The incorporation of BMP in bread dough increases loaf volume and improves its flavour and texture. BMP is easier to incorporate into continuous bread making process.

4.3.5 ROLE OF BUTTER FAT

Addition of butterfat increases loaf volume by 20% yielding a softer crumb structure with improved flavour, texture and internal crumb quality of bread made by mechanical processes. Butterfat in cookies improves spread by interfering with the gluten and starch structures. Milk fat helps to lubricate and weaken the gluten structure and thereby shortens and tenderizes the product. The flavour associated with butterfat is quite distinct. No other fat possesses a comparable flavour. Unfortunately, the price of butterfat has resulted in its decreased use in bakery products.

4.4 MALT AND MALT PRODUCTS

Malt is prepared from cereal grains generally barley. The basic process of malting involves three steps, namely steeping, germination and drying. Barley is preferred for malting mainly because its hull acts as filtration aid, barley grain remains firmer than other cereal grains after steeping and barley produces characteristic flavour.

The malt products include malt extracts, malt syrup and dry malt powder. In fermented bakery products, malt contributes maltose, minerals, salts, soluble proteins, dough conditioning enzymes, flavor and colour. The diastatic malt contains appreciable amount of amylases. In wheat flour deficient in amylases, the addition of malt promote sugar production by action of amylases, promote yeast activity and gas production, add flavour and aroma to the finished product. In crackers, diastatic malt improves fermentation and dough conditioning to enhance sheeting and laminating properties of dough, improves crust colour and flavour. Cutting machine cookies will machine better with addition of malt syrup in equal parts with fat and boiling water. Addition of malt also improves shelf life and freshness of bakery products. Malt also improves food values of bakery products, as it is the rich source of calcium, iron, thiamin, niacin and ascorbic acid.

Non diastatic malts with substantially inactivated enzyme activity are used principally to impart flavour and colour to the cookies and other baked products. They also have some effect on texture and nutritive value of the products. Their high content of sugars and low molecular weight dextrin add to the sweetness of the product and at the same time undergo browning reaction (Maillard reaction and Caramelization) and consequently they can impart flavour and colour to the bakery products.

4.5 YEAST FOOD

Fermentable carbohydrates, amino acids, vitamins and minerals are considered essential for desirable growth of yeast cells during fermentation of dough. Ammonium salts, such as ammonium sulfate, ammonium chloride or ammonium phosphate are also added in the formulation to sustain yeast activity. The ammonium salt dissociates to yield ions that are readily absorbed by yeast as a source of nitrogen. Basically yeast foods are required for improving fermentation power of yeast to produce sufficient carbon dioxide gas. This gas gives rise to porous texture in dough which when subjected to baking yield bakery products with superior texture and good eating quality.

4.6 OXIDISING AGENTS

The baking industries rely on a wide range of chemical agents to modify the dough properties and improve the eating quality and shelf life of bakery products. The oxidising agents make the dough stronger and stiffer by cross-linking of gluten proteins by disulfide bonds. The most commonly used oxidising agents are listed below.

Oxidising agent	**Action rate**	**Stage of action**	**Level of Usage (mg/Kg)**
Azodicarbonamide	Fast	Mixing stage	45
Potassium iodate	Fast	Mixing stage	75
Ascorbic acid	Medium	Fermentation	200
Potassium bromate	Slow	Oven	75

1. Azodicarbonamide (ADA)

It was first introduced in the USA in 1962 at a maximum level of 45 mg/kg of flour. ADA has no bleaching effect, and its main feature is its rapidity of improver action, greater than that of any other permitted bread improver with the possible exception of chlorine dioxide.

ADA is not only rapid, but also effective at as low level as of 2-4 mg/kg. ADA has the unique ability to permit the omission of first (or intermediate) proof without the loss of product quality. It is necessary to raise the level by some 5 mg/kg for this purpose. This step has been estimated as being capable of leading to savings of 5% in capital and running costs and maintenance.

As a concomitant of its speed and activity, ADA levels are more critical than those of other oxidants, and variations of about 20% from optimum produce adverse features in the product. For this reason, and uncertainty about the eventual use to which flour may be put, ADA is rarely added at the mill.

2. L-Ascorbic acid (AA)

It is permitted for use in all flour and all types of bread at a maximum level of 200 mg/kg. It is occasionally added to flour at the mill but is usually added by bakers. AA exerts no bleaching effect on flour and is an unusual bread improver in a number of respects. Firstly, it exerts the effects of an oxidizing improver, though it is chemically a reducing agent. It is now known that the mechanism of action involves the conversion of AA to dehydroascorbic acid (DHAA), which is the true oxidizing agent. This conversion requires the presence of molecular oxygen, an enzyme ascorbic acid oxidase present in flour and/or ions of copper and iron. It is now widely

believed that the DHAA oxidizes the sulphyrdryl group of glutathione in a highly specific reaction catalysed by the enzyme glutathione dehydrogenase, the activity of which is high in flour. The major part of the improving effect is completed during and soon after mixing.

AA is the only improver allowed in wholemeal bread production. It assists in the production of the bread of large volume and finer crumb texture that has become so popular in recent years, and which has helped to raise wholemeal consumption to about 15% of all bread to get benefits of dietary fiber. In the production of white bread, AA is almost invariably used in conjunction with chlorine dioxide and/or potassium bromate added to the flour at the mill. There is evidence for synergism between AA and potassium bromate, such that the improving effect of a mixture is greater than can be achieved by either of the improvers alone when used at the same total level. This synergism disappears when oxygen supply is restricted, and the evidence suggests that some thiol groups are uniquely available to AA and others to potassium bromate.

3. Potassium bromate (PB)

It was first recommended for use as a bread improver in 1916, and has been in common use in the USA, UK and many other countries for the last sixty years. It has no flour bleaching effect whatever. Both the miller and the baker add it. One of the miller's main technical and commercial objectives is to market flour of constant performance for breadmaking. Different flours require different improver treatment levels for constant performance and PB, often in conjunction with chlorine dioxide, has been exceptionally useful in controlling this response. Moreover, lower protein flours require higher levels of treatment. The mechanism of PB action is now thought to involve a slow, rate-limiting conversion of bromate to bromite,

which then reacts rapidly with thiol groups. The overall reaction begins when the flour is wetted and proceeds only slowly at room temperature or during proof (up to ca. 40° C). The major effect occurs during the early stages of baking. The overall low rate of reaction is in contrast to those of the other improvers, and is technically useful in that levels of treatment are not particularly critical. A single addition of the maximum permitted level of 50 mg/kg would not give adequate oxidation for 'no-time' processes, and PB is now almost invariably used in conjunction with AA, with which there is synergism.

4. Chlorine dioxide

Chlorine dioxide (ClO_2) is permitted at a maximum level of 30 mg/kg of flour. It is a gas and is only ever added at the flourmill. It was introduced in 1955 as a replacement for 'Agene' (nitrogen trichloride), and it is particularly useful in adjusting the behaviour of flours intended for long fermentation processes. This adjustment is finely controlled and takes an unusually subtle form in that different streams of flour emerging from the milling process can each be treated to their optimum level before combination into the final composite flour for sale. ClO_2 is rarely used as sole improver but usually in combination with PB at 5-15 mg/kg, and alone is not capable of satisfying the improver requirements of the breadmaking processes. ClO_2 is less powerful than ADA but has a similar rapidity of action, at least in the sense that its effect on dough characteristics is immediately detectable on wetting the flour and mixing. For this reason, it is particularly valuable to the craft baker who is not adding any compound improver. Finally, ClO_2 is the only bread improver, which has some associated bleaching action on flour pigments. It is also widely held in the industry that ClO_2 treatment of flour leads to dough with good handling characteristics, particularly valuable if any manual operations are involved.

4.7 REDUCING AGENTS

The substances, which have ability to modify the dough, are termed as dough improvers or dough stabilizers. The dough improvers, which are of primary importance in cookie making, are reducing agents and proteolytic enzymes. These agents bring about weakening effect of gluten, which facilitates spreading of cookies during baking. The dough improvers are used when wheat flour contains high level of proteins.

Reducing agents as well as proteases produce almost the same effect in dough, that is, of weakening, softening and degrading gluten proteins. But these differ in their mode of action. The effect of reducing agents such as L-cysteine, glutathione, and sodium metabisulphite can be reversed by oxidizing agents like potassium bromate while the results produced by proteases cannot be reversed since the enzyme breaks peptide linkages and hydrolyses the proteins into peptides.

Reducing agents are found particularly useful in biscuit/cookie making to improve extensibility of strong dough. This property of reducing agents in biscuit/cookies facilitates production of more of pieces of the product with the same quantity of dough. Most commonly used reducing agent is L-cysteine hydrochloride, action of which is explained below in detail.

L-Cysteine hydrochloride (CySH)

It was first permitted in flour and bread, other than wholemeal, at levels up to 75 mg/kg in 1972. It is also permitted at higher levels in flours for biscuit or pastry manufacture. The major application of cysteine, in the form of the anhydrous hydrochloride or its monohydrate, is in bread making, but it is permitted for the treatment of biscuit flours at levels of up to 300

mg/kg. CySH is a fast acting reducing agent and when used at the proper level, it reduces dough development time remarkably and increases extensibility of dough that suits biscuit production. CySH works very fast in the mixer and depending upon the amount added, it could reduce mixing requirement of flour as much as 50% or more.

The role of the CySH is to break disulphide bonds, which are subsequently re-formed under the influence of the oxidants. ADD thus has many of the advantages of the CBP in terms of savings of fermentation loss, space and time, but without the need for capital expenditure on a special high-speed mixer and its associated control systems. The ADD process has thus found its widest applications in the family baker segment of the industry and where production space is limited, as in in-store bakeries and hot bread shops.

4.8 SURFACTANTS

Surfactants are fatty substances, which act on the interface of protein and starch molecules in dough system. These ingredients are also referred to as emulsifiers. In fermented bakery products such as bread, the surfactants improve the quality of bread with respect to texture, taste and keeping quality. Most commonly used surfactants are mono and diglycerides, calcium steroyl-2-lactylate (CSL), sodium steroyl-2-lactylate (SSL) and diacetyl tartaric esters of monoglycerides (DATEM). Their role in baking is to improve mixing tolerance and uniformity of cell structure of finished products. The most important benefit of surfactants, particularly of DATEM and SSL are that they enable to produce quality bread even with soft wheat flours which are not otherwise suitable for bread making.

Certain surfactants/emulsifiers have the ability to change the degree of spreading of cookie dough as it is baked. The effect comes from altering

the viscosity of the dough. Cookie dough containing sodium stearoyl-2-laetylate or sodium stearoyl fumarate exhibits a marked increase in spreading. This action may result from interaction of the emulsifier with the starch to delay hydration of the starch granule and subsequent gelatinization. The delay of gelatinization permits more complete flow or spread of the dough before the viscosity increase occurring at gelatinization. It has been reported that improvement from surfactants is more pronounced in regular cookies than in fortified cookies and in cookies containing less shortening. Soy lecithin, a natural surfactant, at 1.0% (on flour basis) level improves the quality of cookies from soft wheat. Lecithin may also be used in cookie formula to provide drier dough. Greasiness of cookies with high shortening content is often reduced by the addition of a small amount (0.25 to 0.7 per cent) of lecithin to the dough.

Some emulsifiers such as SSL at 0.5 per cent of the flour can produce finer and more uniform pattern surface cracks. An emulsifier significantly improves the efficiency of shortening in a cookie formula by uniform mixing of fat globules throughout the dough system. The practical benefit in cookie is that the emulsifier can be used to provide improved eating quality and/or to permit a reduction in shortening level.

4.9 ANTI-MICROBIAL AGENTS

Spoilage from microbial growth results in considerable economic loss for both manufacturer and consumer. The microbial infection of bakery products may also cause health problems. The microbial growth in bakery products occurs depending upon the product, packaging, sanitary and storage conditions. There are two basic means to eliminate microbial spoilage of bakery products. The first is a strong sanitation programme and the use of good manufacturing practices. But problems still result even with the best

sanitary and manufacturing practices and thus the second way to eliminate spoilage is the use of anti-microbial agents. The most commonly used ant-microbial agents include acetic acid, sodium acetate, benzoic acid, sodium benzoate, propionic acid, calcium or sodium propionate, sorbic/potassium sorbate. The anti-microbial agents can be used up to 0.3% by weight of flour used. These preservatives check microbial growth by inhibiting cellular enzyme system. Sorbate can be used on the surface of the products because the product is contaminated with mold between the oven and packaging operation. Bacterial spores of *Bacillus subtilis* (bacteria), are inherent to the flour and other ingredients. These spores are primary concern because they form rope, a degradation of protein and starch by bacteria resulting in a soft and sticky bread unappealing to consumers. Addition of 0.5% calcium propionate or potassium sorbate controls rope problem in bakery products. Sorbate is more effective against rope problems.

4.10 SUMMARY

In most baking formulation, the wheat flour is the predominant ingredient. Other ingredients such as yeast, sugar, shortening, milk and milk products, malt and malt products, yeast food, oxidizing and reducing agents, surfactants and anti-microbial agents also contribute towards the improvement of finished bakery product. All these ingredients play specific role in bakery products. The optional ingredients are also added in the formulation to create variety in the products. Milk and milk are traditional components of bakery items and they are used for their several desired functions. They impart high moisture absorption capacity to dough, increase buffering capacity during fermentation and thereby prevent rapid and excessive acidification, facilitate better control of amylase activity, improve tolerance to bromate, minimize the effects of over mixing and enhance flavor and crust color formation.

In wheat flour deficient in amylases, the addition of malt promote sugar production by action of amylases, promote yeast activity and gas production, add flavor and aroma to the finished product. In crackers, diastatic malt improves fermentation and dough conditioning to enhance sheeting and laminating properties of dough, improves crust color and flavor. Cutting machine cookies will machine better with addition of malt syrup in equal parts with fat and boiling water. Addition of malt also improves shelf life and freshness of bakery products. Malt also improves food values of bakery products, as it is the rich source of calcium, iron, thiamin, niacin and ascorbic acid.

The oxidizing agents make the dough stronger and stiffer by cross-linking of gluten proteins by disulfide bonds. Reducing agents as well as proteases produce almost the same effect in dough, that is, of weakening, softening and degrading gluten proteins. But these differ in their mode of action. The effect of reducing agents such as L-cysteine, glutathione, and sodium metabisulphite can be reversed by oxidizing agents like potassium bromate while the results produced by proteases cannot be reversed since the enzyme breaks peptide linkages and hydrolyses the proteins into peptides. In fermented bakery products such as bread, the surfactants improve the quality of bread with respect to texture, taste and keeping quality. There are two basic means to eliminate microbial spoilage of bakery products. The first is a strong sanitation program and the use of good manufacturing practices. But problems still result even with the best sanitary and manufacturing practices and thus the second way to eliminate spoilage is the use of anti-microbial agents.

4.11 KEY WORDS

Whey: It is a co-product of the cheese making process. It is the milk that has undergone a coagulation process through which the casein proteins and milk fat are removed as cheese curd.

Malt: A product prepared generally from barley grains is called malt. The basic process of malting involves three steps, namely steeping, germination and drying.

Surfactants: These are fatty substances, which act on the interface of protein and starch molecules in dough system. These ingredients are also referred to as emulsifiers.

Oxidizing agents: These are the chemicals that make the dough stronger and stiffer by cross-linking of gluten proteins by disulfide bonds.

Reducing agents: These are the chemicals that cause weakening and softening of gluten proteins.

4.12 SELF ASSESSMENT QUESTIONS

1. Enlist general functions of milk and milk products in bakery goods.
2. Classify milk products used as additives in bakery applications.
3. Explain the specific roles of different types of milk products in bakery goods.
4. Why barley is preferred for malt preparation? Discuss role of malt in bakery products.

5. What is the importance of yeast food? Name commonly used yeast food.

6. Which ingredients are known as dough improvers/conditioners? Explain functions of oxidizing & reducing agents in dough system and in enhancing quality of bakery products.

7. Explain mode of action of surfactant. How does it influence the quality of bakery products?

8. Which anti-microbial agents are used in extending shelf life of bakery products?

4.13 SUGGESTED READINGS

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