POST GRADUATE DIPLOMA
IN
BAKERY SCIENCE AND TECHNOLOGY

PGDBST – 05

BREAD INDUSTRY AND PROCESSES

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UNIT 1: BREAD MAKING PROCESS

STRUCTURE

1.0 OBJECTIVES

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

- Status of baking industry
- Bread making procedure
- Types of mixers
- Functions of mixing, moulding, dividing and proving
- Changes during mixing, fermentation and baking

1.1 STATUS OF BAKING INDUSTRY

India is the 2nd largest wheat producing country in the world next only to China. The present production of wheat in India is about 72 million tonnes indicating 6-fold increase in the three decade due to onset of green revolution. The five major wheat producing states in India are U.P., Punjab, Haryana, Bihar and Himachal Pradesh. Unlike in other economically developed nations, bulk of the wheat produced in our country is processed into whole wheat flour for use in various traditional products. About 10 per cent of the total wheat produced is processed into different products like maida, suji, atta, etc. in roller flour mill, which forms the main raw material for bakery and pasta industry. In spite of small quantities of wheat processed in a roller flourmill for use in bakery products, milling and baking industry still remains the largest organised food industry in the country. The turnover of the milling and baking industry is over 4500 crores and likely to increase at a decent rate in the near future.

1.1.1 MILLING INDUSTRY

Milling industry is the oldest and largest agro based industry in the country with an annual turn over of Rs. 2500 crores. There are about 900 roller flour mills in the country producing various milled products. The yield of different products varies depending on their demand which varies from state to state. In northern part of the country, maximum amount of maida and atta are extracted, as there is more demand for maida and atta. However, in southern India the demand for maida and suji is greater. Due to delicencing policy of the government, the number of roller flour mills has considerably increased in recent years. Originally mills were located only in wheat growing areas, which later shifted to port towns where imported wheats are unloaded, but now these have spreaded throughout the country. It is of interest to note that 75% of the mills are now in non-wheat growing areas.

The capacity of the industry registered with the government is close to 75 million tonnes, which is 1½ times the production of wheat. Capacity of most of the mills at present are under utilised as indicated by the fact that only 7 to 8 million tonnes of wheat is processed, though the installed capacity is 15 million tonnes. During the last 6 to 7 years, the installed capacity and wheat processed remained almost constant. The grinding capacity of units range from 30 to 200 tonnes. However, 80% of the total units have the capacity lower than 100 tonnes/day.

The industry in India has reached a turning point and is faced with technical and financial problems. This is because of the decontrol and delicencing policy of the government. Earlier millers had to buy wheat from FCI and sell the products to the nominees of the government. But now the millers are allowed to buy wheat from the open market, hence, they are faced with lack of infrastructure for bulk purchase and storage so as to maintain steady supply of wheat to the mills. Low priority on railways booking for wheat, fixing the stock limit for mills, restriction on financing by relative credit control are some of the other problems. The decontrol policy has resulted in stiff competition among the mills situated in southern non-wheat growing states and northern states, where wheat is easily available at reasonable cost at all times. This has resulted in increase in the number of sick units and also under capacity utilisation of several mills. The delicencing system has contributed further to this problem as several new mills have been started though demand for the products remained the same. This situation changed the wheat products from sellers market to buyers market. Hence, the milling industry has to change and consider milling as a more scientific method rather than traditional system. Hence, only mills, which produce and supply quality products at competitive price, could survive at the present circumstances. Hence, improvement in the technology is necessary to obtain quality of products as well as productivity. To survive in this competitive market, the milling industries should be supplying specific type of flours required by the bakery industry.

1.1.2 BAKERY INDUSTRY

Bakery industry today has an important place in the industrial map of the country. The annual turnover at present is estimated at over 2000 crores. The bakery industry comprises mainly of bread, biscuits, cakes and pastries manufacturing units. Though there are several large and small scale organised units, manufacturing both bread and biscuits, most of the bakery products in India are being produced by unorganised small family units. Bakery products once considered as a sick man's diet have now become essential food items of vast majority of population in India. It is becoming popular even in places where rice has been the staple food. The contributing factors for the popularity of bakery products are urbanisation resulting in increased demand for ready to eat convenient product, availability at reasonable cost, greater nutritional quality, availability of varieties with different textural and taste profiles and better taste. The bakery products have become popular among all cross section of populations irrespective of age group, and economic conditions.

The total numbers of bakery units are not exactly known, however, it has been reported that there are 50 large-scale units producing either bread or biscuits. Among these, 21 units produce only bread while the remaining produces biscuits. However, there are over 5000 small and medium scale units in factory sectors producing both bread and biscuits. There are over 1 lakh units in family scale small units producing various bakery products like bread, biscuits, cookies and pastries. The number of bakery units is maximum in Western region (34.2%) and minimum in

Eastern region (16.0%). The per-capita consumption of bakery products is highest in Maharashtra followed by New Delhi and West Bengal.

1.1.3 CONSTRAINTS OF BAKERY INDUSTRY

Bakery products not only serve as ready to eat convenient food, but also help in increasing the utilisation of surplus wheat produced in the country. Promotion of bakery industry will also create more employment potential. The growth of bakery industry could be much greater if some of the problems faced by them are solved and the major problems are:

(i) Non-availability of quality raw materials

(ii) Lack of knowledge of raw materials for specific product applications

iii) Poor understanding of process equipments and process technology

iv) Ignorance about testing protocols to enhance and maintain the quality of the finished products.

1.1.4 TRAINED PERSONNEL

The other problem faced by the industry is non-availability of trained personnel to manage the industry. The training facilities now available could meet the requirement of small family scale units or for starting a new unit in a small way. However, there is a need for trained personnel who are able to run the semi-mechanised small as well as large bakery units. This requires training not only in science of baking but also on other allied aspects like bakery machineries, hygiene and sanitation, Bakery management, production methods, quality control, and specifications.

1.2 BREAD FORMULATION

Many different types of bread formulations have been developed so far. These formulations are developed in different regions based on the traditional food habits of the people. The main bread types can be classified as under.

1. Pan bread: This type of bread is popular in the economically developed countries including USA, Canada, United Kingdom and European nations.
2. Hearth bread or sour bread: This category of bread is produced with or without lactic acid fermentation. Hearth breads are baked in an open hearth. These breads are becoming popular in France.
3. Flat bread or roti/chappati: This category of bread is popular in Asian countries. The product is unfermented and flat. This baked on a flat hot pan.
4. Rolls and other small fermented breads: These products generally have higher levels of sugar and fat in the formulation and thus typically have sweeter taste and softer bite characteristics.

The basic recipes for bread making include wheat flour, yeast, salt and water. If any one of these basic ingredients is missing, the acceptable product cannot be prepared. Other ingredients are known as optional, for example, fat, sugar, milk and milk product, malt and malt product, oxidants (such as ascorbic acid and potassium bromate), surfactants and anti-microbial agents. Each of these ingredients has specific role to play in bread making. The wheat flour is the main ingredient in bread production. It is primarily responsible for bread structure and bite characteristics. Water transforms flour into a viscoelastic dough that retains gas produced during fermentation and water also provides medium of all chemical reaction to occur. Yeast ferment sugars and produces carbon dioxide gas and ethanol. It, thus, give us porous and leavened bread. Sugar is the source of fermentable carbohydrate for yeast and it also provides sweet taste. Salt enhances flavour of all other ingredients and adds taste to the bread. It also strengthens the gluten network in the dough. Fat makes the bread texture softer and improves its freshness and shelf life. The oxidising agents such a ascorbic acid, potassium bromate, potassium iodate and azodicarbonamide are used at parts per million levels to enhance dough strength loaf volume and softness. Surfactants are used as anti-staling agents. Calcium propionate is used as prevent mold growth.

The general formulation of white pan bread is as follows:

Sr. No	Ingredients	Percentage
1.	Flour	100
2.	Yeast	2-4
3.	Salt	2
4.	Sugar	6
5.	Fat	2
6.	Water	~60

1.3 BREAD MAKING PROCEDURE

The following steps are generally considered essential for the production of good quality bread.

1.3.1 SIEVING

The flour is generally sieved before using in bread primarily for following reasons:

1. To aerate the flour
2. To remove coarse particles and other impurities
3. To make flour more homogeneous.

1.3.2 WEIGHING

The next step is weighing of different ingredients as per formulation. Minor ingredients have to be weighed more precisely. Salt, sugar, oxidizing agents and yeast are added in solution form. Yeast is added as a suspension, which is mixed well each time before dispensing. Sequence of addition of ingredients also affects the dough characteristics. Generally shortening and salt are added after the clean up stage.

1.3.3 MIXING

Mixing of flour and ingredients involves i.e. hydration & blending, dough development and dough breakdown. The process of mixing begins with hydration of the formula ingredients. The mixing, whilst the flour is hydrating, brings about development of the gluten network in dough, 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 it achieves a point of maximum consistency or minimum mobility. This is the point to which dough should be mixed for producing bread of superior loaf quality. At this stage the dough is converted into a viscoelastic mass from thick and viscous slurry. At this stage the gluten forms a continuous film or sheet suitable for processing into bakery applications. If mixing is continued beyond this point, mechanical degradation of the dough occurs resulting in the breaking down of the dough network. 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 will create problem in dough handling and frequent break down in the plants and ultimately results into processing losses. Various stages of mixing are explained below:

1. Initial hydration stage

At this stage ingredients are blended and homogenised. The dough begins to wet and sticky.

2. Pick up stage

At this stage the hydration of ingredients is advanced and they are aggregated into wet mass. The wet mass is uneven and wet. The gluten begins to develop in the dough system..

3. Clean up stage

Further mixing develops the gluten network in the dough. Dough becomes extensible and elastic. Dough forms a cohesive mass and ceases to stick to mixing blades and walls of mixer.

4. Development stage

The dough becomes more viscoelastic in nature. It gives silky and shine character.

5. Optimum stage

This is the optimum mixing stage. Dough at this stage is elastic, silky and smooth. Forms thin membrane of uniform thickness when stretched without breaking. It is the right stage to process dough for bread making.

6. Break down stage

Beyond optimum stage the dough becomes increasingly soft, smooth and highly extensive. Dough also becomes sticky and demonstrates poor machinability.

Mixing time

The mixing time varies with the type of flour, type of mixer, speed of mixing arm, presence of salt or shortening, additive, particle size as well as damaged starch content of flour. A flour of good bread quality flour should have medium to medium-long dough development and mixing time. If the mixing time is very short the flour can easily be over mixed, and if the mixing time is very long it might never reach its optimum. On the other hand, biscuit quality flour will develop in to dough rapidly.

Flour with weak gluten develops more quickly, whereas strong and 'extra-strong' flours need a longer time to mix to peak dough resistance, suggesting that the mixing requirement of a flour is related to its gluten protein composition. It has been observed that gliadin and its subgroups decreases the mixing time of a flour. The mixing time is related to the size of gliadin proteins. Mixing time decreases in the order ω1- > γ- > β- > α-gliadins in accordance with their molecular size and/or charge. Higher glutenin in flour favours bread quality, and higher proportion of gliadin in flour favours biscuit quality.

It is generally considered that glutenin subunits 5+10, 17+18, 7+8, 1 and 2* are related to longer mixing times and dough strength, whereas subunits 6+8, 2+12, 3+12 and 20 are related to shorter mixing times and dough weakness. Both quantitative and qualitative effects may contribute to quality differences associated with specific high M_r glutenin subunit alleles. The high M_r glutenin subunits 5+10 and 2+12, 17+18 and 20, also 1 and 2* are produced in similar quantities and, therefore, the qualitative differences in these subunits are believed to be responsible for their different effects on mixing time and dough strength.

1.3.4 FERMENTATION

Optimally mixed dough is subjected to fermentation for a suitable length of time to obtain light aerated porous structure of fermented product. Fermentation is achieved by yeast (*Saccaromyces cerevisiae).* The yeast in dough breaks down the sugars to carbon dioxide and ethanol. The gas produced during fermentation leavens the dough into foam. The foam structure of dough is discrete and has stability during fermentation. When fermented dough is baked, the foam structure gets converted into sponge structure that is responsible for aerated structure of breadcrumb. The conditions under which fermentation occurs affect the rate of carbon dioxide production and flavour development in the dough. The temperature and relative humidity conditions are particularly important for yeast activity and gas production. In the temperature range of 20 to 40ºC, the yeast fermentation rate is doubled for each 10ºC rise in temperature. Above 40ºC yeast cells are started to get killed. The yeast performs well at 30-35ºC and relative humidity of 85 % and above. The optimum pH range for yeast is 4 to 6. Below pH 4 the yeast activity begins to diminish and it is inactivated below pH 3. Osmotic pressure also affects the activity of yeast.

1.3.5 KNOCK BACK

Punching of dough in between the fermentation periods increases gas retaining capacity of the dough. The knock back has the objectives of equalizing dough temperature throughout the mass, reducing the effect of excessive accumulation of carbon dioxide within the dough mass and introduces atmospheric oxygen for the stimulation of yeast activity. The knock back also aids in the mechanical development of gluten by the stretching and folding action. Usually knock back is done when 2/3 of the normal fermentation time is over.

1.3.6 DOUGH MAKE-UP

The function of dough make-up is to transform the fermented bulk dough into properly sealed and moulded dough piece, when baked after proofing it yields the desired finished product.

Dough make-up includes (a) scaling; (b) rounding, inter-mediary proof and moulding.

Scaling or dividing

The dough is divided into individual pieces of predetermined uniform weight and size. The weight of the dough to be taken depends on the final weight of the bread required. Generally, 12% extra dough weight is taken to compensate for the loss. Dividing should be done within the shortest time in order to ensure the uniform weight. If there is a delay in dividing, corrective steps should be taken either by degassing the dough or increasing the size of the dough. The degassers are essentially dough pumps which feed the dough into the hopper and in the process remove most of the gas. The advantages of using degassers are: (i) more uniform scaling, (ii) uniform pan flows and (iii) uniform grain and texture of bread.

Rounding

When the dough piece leaves the divider, it is irregular in shape with sticky cut surfaces from which the gas can readily diffuse. The function of the rounder is to impart a new continuous surface skin that will retain the gas as well as reduce the stickiness thereby increasing its handling. Rounder are of two types i.e. umbrella and bowl type.

Intermediate proofing

When the dough piece leaves the rounder, it is rather well degassed as a result of the mechanical it received in that machine and in the divider. The dough lacks extensibility and tears easily. It is rubbery and will not mould easily. To restore more flexible, pliable structure which will respond well to the manipulation of moulder, it is necessary to let the dough piece rest while fermentation proceeds.

Intermediate proofer contains a number of trays that are chain driven. The dough piece is deposited in the tray with completed number of laps at predetermined rate. Average time at this stage ranges from 5 to 20 min.

Moulding

The moulder receives pieces of dough from the inter-mediate proofer and shapes them into cylinders ready to be placed in the pans. Moulding involves three separate steps; (i) sheeting; (ii) curling; and (iii) scaling.

Sheeter degasses the dough and sheeted dough can be easily manipulated in the later stages of moulding. Sheeting is accomplished by passing the dough through 2 or 3 sets of closely spaced rolls that progressively flatten and degas the dough. The first pair of rolls is spaced about 0.25" apart where the degassing takes place. The successive two rollers are spaced 0.125" and 0.06" apart for optimum grain and texture development in the finished products.

The sheeted dough piece next enters the curling section. A belt conveyor under a flexible woven mash chain that rolls into a cylindrical form carries the sheeted dough. The rolling operation should produce a relatively tight curl that will avoid air entrapment. The curled dough piece finally passes under a pressure board to eliminate any gas pockets with in and to seal the same.

Panning

The moulded dough pieces are immediately placed in the baking pans. Panning should be carried out so that the seam of the dough is placed on the bottom of the pan. This will prevent subsequent opening of the seam during proofing and baking. Optimum pan temperature is 90°F.

1.3.7 PROVING OR PROOFING PROCESS

Proving or proofing refers to the dough resting period during fermentation after moulding has been accomplished and moulded dough pieces are placed in bread pans or tins. During this resting period the fermentation of dough continues. The dough finally proofed or fermented in baking pan for desired dough height. It is generally carried out at 30-35ºC and at 85% relative humidity. Proofing takes about 55-65 minutes. During proofing the dough increases remarkably in volume. The dough expands by a factor of 3-4 during proofing. During proofing care has to be taken that the skin of dough remains wet and flexible so that it does not tear as it expands. A high humid condition is also required to minimise weight loss during proving. Temperature, humidity and time influence proofing. Proof temperature depends on the variety of factors such as flour strength, dough formulation with respect to oxidants, dough conditioners, type of shortening, degree of fermentation and type of product desired. During proofing lower humidity gives rise to dry crust in the dough. Excessive humidity leads to condensation of moisture. Dough is generally proved to a constant time or constant height.

1.3.8 THE BAKING PROCESS

After proofing the dough is subjected to heat in a baking oven. Baking temperature generally varies depending up on oven and product type but it is generally kept in the range of 220-250ºC. During baking the temperature of dough centre reaches to about 95ºC in order to ensure that the product structure is fully set. When the dough is placed in the oven, heat is transferred through dough by several mechanisms such as convection, radiation, conduction, and condensation of steam and evaporation of water. Heat transfer inside dough is said to occur through the mechanism of heat conduction and evaporation/condensation. The baking time of bread may range from 25 to 30 minutes depending up on size of bread loaf. After baking, bread is cooled prior to packaging to facilitate slicing and to prevent condensation of moisture in the wrapper. Desirable temperature of bread during slicing is 95-105°F.

1.4 FUNCTIONS OF MIXING

There is some difference between mixing and kneading of a flour to dough. Mixing refers to homogenisation of formula ingredients, whereas kneading is the development of the dough or gluten network by mechanical means. Mixing of flour and other formula ingredients is carried out to serve following functions.

1. To disperse the formula ingredients uniformly.
2. To blend and hydrate the dough ingredients.
3. To develop the gluten structure or network in the dough in order to enable the dough to retain gas without rupture.
4. To aerate the dough to serve two purposes a) to provide gas nuclei for carbon dioxide produced during fermentation and b) to provide atmospheric oxygen for oxidation of dough and yeast activity.

1.5 TYPES OF MIXERS

Mixers used to develop dough vary widely in size and intensity of mixing action. Many mixing machines are available those still work similar to hand mixing. A series of other mixers have also been developed, in which a very high speed mixing is practised and dough is mechanically developed within a few minutes. The mixers commonly used for mixing of wheat dough are classified as under.

1. Low speed mixer: This type of mixer takes longer time to develop the dough for bread making. Example of this type is the twin arm mixer. Gentle mixing is achieved with low rate of work input. These mixers mimic hand mixing. The arm of mixer lift, stretch and fold the dough during kneading. Typical mixing times taken by these mixers are between 15 and 25 minutes and mixing depends on the machine capacity and types of ingredients. Capacity of these mixers may range from 50 to 300 kg. They are effective for bending of delicate fruit pieces without damage or mixing of weaker dough.

2. **Spiral mixers**: It is commonly used mixer in the industry. The machine is fitted with a spiral-shaped mixing hook that rotates on a vertical axis. This mixer can operate on slow and fast speed. Th slow speed mode is used for weaker dough and high speed mode is used for mixing of strong flour.

3. **High speed and twin-spiral mixers**:This category of mixer imparts high level of mechanical energy to the dough in a short period of time. It can mix a dough within 5 minutes. High-speed mixers are available in multiple design. The bowl of these mixers remains static during mixing. The capacity may vary from 50 to 300 kg dough. The cooling arrangements are required in these mixers as energy imparted to the dough during mixing is enormous and hence dough temperature become very high on completion of mixing.

4. **Chorleywood bread process compatible mixers:** This category of mixer must be compatible with CBP in delivering a fixed amount of energy in a short period of time usually 11 Wh/kg of dough in 2-5 minutes. The mixing bowl is mounted on horizontal axis and it can be tilted to dispense dough after mixing is accomplished. Important features of such mixers are:

- automatic control of mixing cycle

- automatic ingredient feed systems
- an integrated washing and cleaning systems

1.6 FUNCTIONS OF MOULDING AND DIVIDING

Important functions of dividing and moulding are:

1. To divide the bulk dough in desired shape and size.
2. To divide the dough into individual pieces of uniform weight.
3. To improve grain and texture of bread.
4. To improve appearance and acceptability of bread.

1.7 FUNCTIONS OF PROVING

Final proof has the following functions:

1. To relax the dough from the stress received during previous operations.
2. To facilitate production of gas in order to give desired volume to the dough.
3. To mellow gluten to extensible character for oven rise.

1.8 CHANGES DURING MIXING, FERMENTATION AND BAKING

1.8.1 CHANGES DURING MIXING

1. Formation of three-dimensional net work of protein: Mixing of bread formula ingredients brings about physicochemical changes in the dough and its components. The dough constituents particularly gluten proteins interact to form a three dimensional structure to the dough.

As a result of this change, the dough becomes extensible and elastic that is responsible for gas retention and bread quality.

2. Sulphydryl-disulphide interchange reactions: Mixing brings about SH-SS interchange, which matures and develops the dough for further processing into bread.

3. Oxygen incorporation into the dough, which helps in oxidation as well as the formation of nuclei for the formation of gas cells.

4 Starch, lipid and protein complex formation, which is responsible for gas retention during baking.

5. Mixing also increases the temperature of dough: The temperature of the dough has great influence on the overall quality of bread. The temperature of the dough out of the mixer should be within the range of 25-28°C. The dough temperature depends on the temperature of different ingredients, friction factor of the machine, heat of hydration of ingredients and their specific heat. The temperature of the mixed dough can be controlled by altering the temperature of water used for preparing the dough that can be calculated from the formula.

Water temperature = 3 (desired dough temperature) - (RT + PT + FF)
where, RT is room temperature, FT is flour temperature, and FF is the friction factor. Temperature of water can be brought down by cooling or by adding ice by replacing part of water.

$$\text{Weight of ice} = \frac{\text{Weight of water (tap water temp. - Calculated water temp.)}}{\text{(Tap. Water Temp. + 112)}}$$

Adopting mechanical refrigeration can also control dough temperature.

1.8.2 CHANGES DURING FERMENTATION

Dough after optimum mixing is subjected to fermentation at around 30ºC and 85% relative humidity for a suitable length of time. Fermentation is essential for obtaining light aerated loaf of bread. During fermentation several desired physicochemical changes occur in the dough system, which is explained below.

1. Physical Changes

a) Increase in volume due to production of CO_2
b) Increase in temperature
c) Increase in the number of yeast cells
d) Loss of moisture
e) Changes in the consistency of dough. The dough becomes soft, elastic as well as extensible.

2. Chemical changes

a) Reduction in pH: The pH of dough is reduced from 5.5 to 4.7 due to formation of acids like acetic acid yeast activity.
b) Formation of maltose sugar by diastatic enzymes acting on starch.
c) Development of dough due to the cessation of S-S bonds and formation of new SH and SS groups, which improve the gas retention property of dough.
d) Conversion of starch into simple sugar by diastatic enzymes which is then converted into CO_2 and alcohol by the following group of enzymes present by yeast:

$$\text{Starch} \xrightarrow{\text{Diastase}} \text{Maltose + Dextrin}$$

$$\text{Maltose} \xrightarrow{\text{Maltase}} \text{Dextrose}$$

$$\text{Dextrose} \xrightarrow{\text{zymase}} \text{Carbon dioxide + alcohol}$$

1.8.3 CHANGES DURING BAKING

As the dough enters into baking oven it undergoes several physical and biochemical changes. These changes are described below:

A. Physical

1. Oven-spring: The dough expands rapidly in first few minutes in the oven. This sudden rise is called oven-spring. Several factors are held responsible for oven-spring. The gases heat and increase in volume, water, carbon dioxide and ethanol evaporates. All this causes increase in internal pressure of dough and the dough rise rapidly in the initial stage of baking. Yeast activity decreases as the dough warms and the yeast is inactivated at 55ºC.

2. Crust formation: The dough that is exposed to oven temperature develops skin and forms a crust as moisture evaporates from surface of dough evaporates very rapidly. The crust provides the strength of the loaf.

B. Chemical

1. Yeast activity: Activity of yeast depends on the temperature. Yeast activity increases very rapidly initially as the dough is placed in the oven but it is inactivated at 55°C.

2. Starch gelatinisation: Starch begins to gelatinise at about 60ºC. The dough contains limited water to gelatinise the starch completely. This limited gelatinisation of dough helps in gas retention and setting of bread texture.

3. Gluten coagulation: Starch gelatinisation is associated with absorption of water while gluten denaturalisation is associated with the removal of water. Gelatinisation sets in when the temperature is around 74°C, and continues till the end of baking. In this process, gluten matrix surrounding the individual cells is transformed into a semi-rigid film structure. Thus, a major change that takes place during the oven process is the redistribution of water from the gluten phase to the starch phase.

4. Enzyme activity: The action of amylase on starch increases with temperature approximately doubling for every 10°C rise. At the same time, heat inactivation of the enzymes also commences. ß-amylase denature at lower temperature (57 to 71°C) as compared alpha-amylase which denatures at temperatures ranging from 65 to 95°C. Insufficient amylase activity can restrict loaf volume because the starch becomes rigid soon, whereas excess amylase activity may cause collapse of loaf.

5. Browning reaction: The browning reaction starts at around 160°C. It is the result of heating reducing sugars with proteins or other nitrogen containing substance to form coloured compounds, known as melanoidins. This reaction also imparts colour and flavour to the bread.

1.9 SUMMARY

India is the 2nd largest wheat producing country in the world next only to China. The present production of wheat in India is about 72 million tonnes indicating 6-fold increase in the three decade due to onset of green revolution. About 10 per cent of the total wheat produced is processed into different products like maida, suji, atta, etc. in roller flour mill, which forms the main raw material for bakery and pasta industry. In spite of small quantities of wheat processed in a roller flourmill for use in bakery products, milling and baking industry still remains the largest organised food industry in the country. The turnover of the milling and baking industry is over 4500 crores and likely to increase at a decent rate in the near future.

Many different types of bread formulations have been developed so far. These formulations are developed in different regions based on the traditional food habits of the people. The recipe for bread making includes wheat flour, yeast, salt and water. If any one of these basic ingredients is missing, the acceptable product cannot be prepared. Other ingredients are known as optional, for example, fat, sugar, milk and milk product, malt and malt product, oxidants (such as ascorbic acid and potassium bromate), surfactants and anti-microbial agents. Each of these ingredients has specific role to play in bread making. Critical steps of bread making process are mixing, fermentation and baking.

1.10 KEY WORDS

Pan bread: This type of bread is popular in the economically developed countries including USA, Canada, and United Kingdom and European nations. This type of bread is baked in bread tin or pan.

Hearth bread or sour bread: This category of bread is produced with or without lactic acid fermentation. Hearth breads are baked in an open hearth. These breads are becoming popular in France.

Flat bread or roti/chappati: This category of bread is popular in Asian countries. The product is unfermented and flat. This baked on a flat hot pan.

Rolls and other small fermented breads: These products generally have higher levels of sugar and fat in the formulation and thus typically have sweeter taste and softer bite characteristics.

Knock back: This is also known as punching which is mixing of dough during fermentation for short time. Punching of dough in between the fermentation periods increases gas retaining capacity of the dough.

Proving or proofing: It refers to the dough resting period during fermentation after moulding has been accomplished and moulded dough pieces are placed in bread pans or tins.

1.11 SELF ASSESSMENT QUESTIONS

1. What are the main constraints of baking industry?

2. Discuss the present status of milling & baking industry in India.

3. Classify bread and discuss in brief the role of ingredients in bread production.

4. Give a brief description of general bread making procedure.

5. How mixing is important in bread quality?

6. Discuss different types of mixing machine used in bread industry.

7. Why bread dough is subjected to moulding, dividing and proving operations?

8. Discuss physical and biochemical changes in dough during mixing, fermentation and baking.

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UNIT II: DEVELOPMENTS IN BREAD MAKING PROCESSES

STRUCTURE

2.0 OBJECTIVES

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

- Major bread making processes
- Advantages and limitations of various bread processes
- Packaging of bread

2.1 INTRODUCTION

Several bread making processes are available around the world and great varieties of breads are produced using these processes. Bread making processes have been modified to suit modern and fast processing of wheat flour into bread. The earlier processes had requirements of long fermentation and large space requirements. The recently developed processes are no time to minimum time processes, which are fast, labour and space effective. However, all these processes have single aim to convert wheat flour and other ingredients into palatable bread products. The bread making processes have following common processing steps for converting wheat flour into bread.

1. Mixing of flour with other ingredients to develop a dough or gluten network. Each of bread making method has a requirement of mixer for kneading the ingredients together to form cohesive dough.
2. Fermentation to mature or ripen the dough.
3. Baking to transform aerated dough into baked product.

2.1.1 FUNCTIONS OF BREADMAKING PROCESS

All bread making processes are developed keeping in view to achieve the following

1. Development of a gluten network in the dough to retain gas and produce spongy bread texture.
2. Incorporation of air bubbles within the dough during mixing.
3. Creation of particular flavour compounds in the dough.
4. A preliminary modification of the shape of the divided dough pieces.
5. Fermentation and expansion of the shaped dough pieces during proof'ing. Further expansion of the dough pieces and fixation of the final bread structure during baking.

The main differences between individual and groups of bread making processes are normally associated with mixing and kneading, air incorporation, and the creation and development of the gluten structure. The processing stages such as scaling, proving and baking, are common to most bread making processes and differences between individual bakeries tend to be in the type of equipment used and small variations in conditions that are applied in the bakery equipment, e.g. time and temperature.

2.2 MAJOR BREAD MAKING PROCESSES

The processes used for commercial production of bread differ principally in achieving dough development. These may be classified into three broad processing groups although there are numerous variations and also elements of overlap between each of the individual groups.

2.2.1 LONG FERMENTATION PROCESSES: Straight dough bulk fermentation process and Sponge & dough process are example, which falls under this group. In these processes resting periods (floor-time) for the dough in bulk after mixing and before dividing are longer. In the case of straight dough method all the ingredients are mixed in one step, whereas in sponge and dough process, a part of the dough formulation receives a prolonged fermentation period before being added back to the remainder of the ingredients for further mixing to form the final dough.

2.2.2. **RAPID PROCESSES**: In these methods a very short or no period of bulk fermentation is given to the dough after mixing and before dividing.

2.2.3 **MECHANICAL DOUGH DEVELOPMENT PROCESS**: Here a primary function of mixing is to impart significant quantities of energy to facilitate dough development, and the dough moves without delay from mixer to divider. The dough is developed by high level of energy imparted at the stage of mixing.

2.3 STRAIGHT DOUGH BULK FERMENTATION PROCESS

The dough is fermented in bulk. This is the most traditional and most 'natural' of the bread making process. Essential features of bulk fermentation processes are summarized as follows:

1. Mixing of all the ingredients to form homogeneous dough.
2. Fermentation of the dough so formed in bulk for a prescribed time (floortime), depending on flour quality, yeast level, dough temperature and the bread variety being produced.
3. Dough formation for bulk fermentation is usually achieved by low-speed mixers or may be carried out by hand.

In general, the stronger flour will require longer fermentation to achieve optimum dough development. So higher protein flours require longer bulk fermentation times than lower protein flours. The supplementation of flours with dried, vital wheat gluten to increase the protein content of weaker base flours is a common practice in many parts of the world. Gluten supplementation is less successful in bread making processes where mixer has lower speed as seen in the case of long processes. Flours used for bulk fermentation processes should be low in cereal alpha-amylase because of the potential softening effects on the dough handling character with extended bulk resting time.

During bulk fermentation the dough develops by enzymatic action. Since enzymatic actions are time and temperature dependent, therefore, adjustment of added water levels will have to be made to compensate for these changes. An outline of a straight dough method is shown in Figure 2.1.

Weigh all ingredients

↓

Develop dough by mixing & ferment (2½ hr)

↓

Punching & ferment for 55 min

↓

Dividing & intermediate proofing (25 min)

↓

Moulding and putting in bread tins & final proofing (55 min)

↓

Baking

Figure 2.1 A straight dough bulk fermentation bread process.

2.4 SPONGE AND DOUGH BULK FERMENTATION PROCESS

The key features of sponge and dough processes are:

1. In this process a part flour (generally two-thirds), part of water and yeast are mixed just to form loose batter or dough (sponge).

2. Sponge is allowed to ferment for up to 5hr.

3. Mixing of the sponge with the remainder of the ingredients to develop the dough optimally.

4. Immediate processing of the developed dough with a short period of bulk fermentation period

An outline of a sponge and dough method is shown in Figure 2.2.

Weigh part of flour, water and whole yeast

↓

Mix to loose dough (sponge) & ferment for 3-5 hr

↓

Add rest ingredients & develop the dough and rest for 40 min

↓

Dividing & intermediate proofing (20 min)

↓

Moulding and putting in bread tins & final proofing (55min)

↓

Baking

Figure 2.2 Sponge and dough bread process.

Role of the sponge

The primary role of the sponge is to modify the flavour and to contribute to the development of the final dough through the modification of its rheological properties. The flavour is developed by yeast in the sponge. The sponge fermentation conditions should be closely controlled and care should be taken to avoid a build-up of unwanted flavours by thorough cleaning of storage containers after use.

During the sponge fermentation period, the pH decreases with increasing fermentation time. The rheological character of the gluten formed during initial sponge mixing will change as fermentation progresses, with the sponge becoming very soft and losing much of its elastic character. As standing time increases, the condition of the sponge increasingly resembles over fermented dough. The low pH of the sponge and its unique rheological character are carried through to the dough where they have the effect of producing a softer and more extensible gluten network after the second mixing. In many cases the addition of the sponge changes the rheological character of the final dough enough to render further bulk resting time unnecessary, so that dividing and moulding can proceed without further delay.The sponge and dough process produces soft bread with uniform crumb grain structure. The sponge and dough process has tolerance to time and other conditions.

2.5 RAPID PROCESSING

Under this category, the processes are evolved based on different combinations of active ingredients and processing methods. All processes covered under this group include improvers to assist in dough development and the reduction fermentation period. The prominent examples include activated dough development, no-time doughs with spiral mixers and the Dutch green dough process. Each of these processes are discussed below:

2.5.1 ACTIVATED DOUGH DEVELOPMENT (ADD)

This process was developed in the USA during the early 1960s and became popular in smaller bakeries in the USA and the UK thereafter. Its essential features are:

1. The use of a reducing agent generally L-cysteine Hydrochloride, proteolytic anzymes and ascorbic acid to reduce mixing time of flour.
2. The use of oxidizing agents other than added at the flourmill.
3. The use of a fat or an emulsifier.
4. Extra water in the dough to compensate for the lack of natural softening.
5. Extra yeast (1-2%) to maintain normal proving times.

The ADD process has undergone a number of changes from its introduction and now probably no longer exists in its original form. When ADD was first introduced, potassium bromate was commonly used together with ascorbic acid and L-cysteine hydrochloride. L-cysteine works very fast in the mixer and depending upon the amount added can reduce the mixing requirement of a flour as much as 50% or more. Proteolytic enzymes can also be used to reduce the dough development time. They give only 15 to 20 per cent reductions in mixing time during the period of dough development in the mixer- due to the short exposure time to the protein. But they keep working after the dough is mixed.

The dough development process in ADD is mainly chemically induced, low-speed mixers could be employed. This allowed small bakers to continue using their existing low-speed mixers and eliminate bulk fermentation without purchasing the new high-speed mixers being developed for mechanical dough development processes in the 1950s and 1960s. However, with time many of the smaller bakers changed to spiral-type mixers, which allowed them to move to improver formulations with fewer 'chemicals' at a time when consumer attitudes to 'additives' were changing.

A short period of bulk fermentation before dividing is considered beneficial for ADD product quality. Sponges could be added to change bread flavour, if required. Final dough temperatures are kept in the region of 25-27°C.

2.5.2 NO-TIME DOUGHS WITH SPIRAL MIXERS

No-time doughs process is also known as short-time dough process. In smaller bakeries the spiral mixer has taken over as the main type of mixer being used. Spiral mixers have a number of advantages for no time breadmaking processes. The advantages of this method are the elimination of long fermentation time, savings in expensive equipment, labour and energy cost. The process involves developing dough chemically or mechanically by employing improvers and malts.

2.5.3. THE DUTCH GREEN DOUGH PROCESS

This process was developed in the Netherlands. It is included under this process group as the dough after mixing passes without delay to dividing, although some resting of dough is involved in the total process. The essential features of the process are:

1. Mixing in a spiral-type mixer or extra mixing in a speeded-up conventional low-speed mixer.
2. Dividing of dough immediately after mixing.
3. The dough is then rounded and given a resting period of of 35-40 min.
4. The dough is re-rounded and given a further resting period before final moulding.

The name 'green' dough refers to the fact that after mixing the dough is considered to be underdeveloped or 'green' in bakery units. Dough development continues in the resting periods or fermentation period after each rounding. When first introduced, two or three resting periods were used. Now it is more common to use one, but to a lesser extent two resting periods.

Involvement of improvers and other ingredients in rapid processing

Although it is possible to make no-time doughs without additional ingredients, such as with the traditional Dutch green dough process, it is common for improvers to be added to assist dough development in the absence of bulk fermentation time. The compositions of improvers, which are used, vary widely, although the most common ingredients are ascorbic acid, enzyme-active materials and emulsifiers.

Most no-time dough processes use flours of the stronger type with protein contents of 12% or higher. Water additions will be higher in short dough processes than in bulk fermentation. The mixer type also influences the amount of water level used, with some doughs being softer and stickier when taken out of one machine compared with another. Often this initial stickiness is lost in the first few minutes after dough comes out of mixing the machine.

2.6 MECHANICAL DOUGH DEVELOPMENT

In such method, the dough development is achieved mainly in the high speed-mixing machine. The maturation or ripening is achieved through the addition of improvers, extra water and a significant planned level of mechanical energy.

The mechanical dough development was first successfully developed in the 1950s. This process was given the name of ‘Do-maker’. The 'Do-maker' method produces bread loaf with fine and uniform cell structure, which eventually proved to be unpopular with majority of consumers, and today few installations remain in use. The 'Do-maker' used a continuous mixer.

In 1958 the British Baking Industries Research Association at Chorleywood, UK, which was later merged with the Flour Milling and Baking Research Association FMBRA) and more recently unified with the Campden & Chorleywood Food Research Association) investigated the mechanical development of dough. The process developed by this organization is known as Chorleywood Breadmaking Process (CBP).

2.6.1 CHORLEYWOOD BREAD PROCESS (CBP)

The principle involved in the production of fermented foods by the CBP remain the same as those first published by the Chorleywood team in 1961, although the practices have changed with changes in ingredients and mixing equipment. The essential features of the CBP are:

1. Mixing and dough development takes place in a single operation lasting between 2 and 5 minute at a fixed energy input of 11Wh/kg of dough.
2. A combination of fast and slow acting oxidizing agents such as potassium bromate and potassium iodate.
3. Addition of a high melting point fat, emulsifier or fat and emulsifier combination.
4. Use of extra water to adjust dough consistency to be comparable with that from bulk fermentation;
5. Use of extra yeast to maintain final proof times comparable with those obtained with bulk fermentation;
6. Control of mixer headspace atmosphere to achieve given bread cell structures.

The main difference between the CBP and bulk fermentation processes lies in the rapid development of the dough in the mixer rather than through a prolonged resting period. The aim of both processes is to modify the protein network in the dough to improve its ability to retain gas from yeast fermentation in the prover. In the case of the CBP this is achieved within 5 min of starting the mixing process.

2.7 FROZEN DOUGH PROCESS

This process is generally used for retail or household baking for fresh bread, rolls and Danish pastries. The end product cost could be maintained at par with the method of production by saving on labour and other overheads. The frozen doughs require longer proof time due to decreased yeast cells during freezing cycle. The doughs are made usually from strong flour or by using additional vital dry gluten. The presence of emulsifiers and oxidants overcome the deleterious effect during freezing.

2.8 MICROWAVE PROCESS

Microwave baking of bread though initiated in 1960s, it actually picked up during 90s. In this process the heating begins immediately and it is very fast. The heating depends greatly on moisture, mass, dielectric properties, geometry, etc. The processing cost could be reduced and capacity increased by this process. The microwaves fall in the frequency range of 300 MH (10^6) to 300 GHz (10^9). Heating is caused due to the ionic induction and dipole movement influenced by rapidly changing polarity of electric field. The microwave heating is quite expensive in terms of equipment and operation cost.

2.9 ADVANTAGES AND LIMITATIONS OF VARIOUS BREAD PROCESSES

2.9.1 LONG BULK FERMENTAION PROCESSES

The advantages of straight dough and sponge & dough bulk fermentation processes are as follows:

1. These processes are traditional processes where fermentation time is longer and hence, flavour development in such processes is considered better.
2. Taste of bread is superior.
3. Cell structure of breadcrumb is more preferred.
4. Lesser requirement of chemicals and yeast as time available is sufficient for dough ripening.
5. Less cost of plant & machinery as simpler & less sophisticated equipments such as low speed mixers are used.

Limitations

1. More space requirement for processing.
2. These processes take longer overall time to convert flour and other formula ingredients into bread.
3. More expenses on labour hiring.
4. Product quality may vary from batch to batch due to poor process control.

2.9.2 MECHANICAL DOUGH DEVELOPMENT & CHEMICAL DOUGH DEVELOPMENT PROCESS

Advantages:

1. A drastic reduction in processing time.

2. Space savings from the elimination of long bulk fermentation.
3. Improved process control and reduced wastage in the event of plant breakdowns
4. More consistent product quality.
5. Financial savings from higher dough yield through the addition of extra water and retention of flour solids that are normally fermented by yeast in long fermentation

Limitations:

1. Faster working of the dough is required because of the higher dough temperatures used.
2. A second mixing will be required for the incorporation of fruit into fruited breads and buns.
3. In some views, a reduction of bread crumbs flavour because of the shorter processing times.
4. Use of chemicals not considered wholesome by consumers.

Processes where length of bulk fermentation is kept longer give better flavour in the product. If increased flavour is required in breadcrumb made by the CBP or no-time dough or chemically developed dough, then the use of a sponge or a flour brew is recommended. Bulk fermentation after the completion of dough mixing in these processes is not recommended because of the adverse changes that occur in the dough and the loss of subsequent bread quality.

2.10 PACKAGING OF BREAD

A wide variety of bakery products are available including bread, biscuits, cookies, cakes, buns, rusk, etc. Bakery industry is one of the largest foods processing industries in India and is rapidly growing because of increased demand for baked goods as a result of industrialization and urbanization. Packaging of baked goods constitutes 10-30% of the entire cost of the pack.

The main functions of a package are to (i) containing the product (ii) to protect the product and (iii) to help in selling of the product. To perform these functions satisfactorily, the packaging materials should have:

1. Necessary strength properties to withstand conditions of processing, storage and transport.

2. Should protect from environmental factors such as humidity, oxygen, light and heat.

3. Should have desired machinability, heat sealability and printability

4. It should preferably be economic and easily available.

Baked goods are very susceptible to physico-chemical changes under adverse climatic conditions e.g. desiccation in bread, loss of crispness and rancidity in biscuits and microbiological spoilage. So a package designed for these products must take these factors also into consideration.

Packaging requirements for bread

Packaging of bread must ensure hygiene, conserves moisture and prevents staling to keep it in as fresh a condition as possible. The bread crust is dry and the breadcrumb contains moisture up to 40 per cent. The bread crust has to be protected from moisture pick-up and breadcrumb should be protected from evaporation of moisture. A good moisture barrier promotes mold growth and makes the crust soft while in a poor barrier the bread dries out and stales. Staling occurs in 4-7 days after manufacture and is a property of flour, method of baking and storage conditions.

The ideal bread packaging material must be have following properties:

1. A barrier against contaminating agents and ensure a hygienic wrap free from dust etc.

2. To have optimum water vapour transmission rates (WVTR). It should conserve the moisture loss, prevent rapid desiccation and staling. However, preventing condensation of water inside package may cause growth of microbes and softening of the crust.

3. To have requisite physical strength property to provide some physical protection against bruising of the product during transportation and storage.

4. The packaging material should possess good stiffness, tensile strength and tear resistance which are required during bag forming, filling and sealing operation.

5. It should also resist the effect of creasing and folding.

6. It should have good printing surface and appearance.

7. Should be economical in keeping with the cost of the product.

8. It should provide user facilities such as easy opening and re closure.

Bread coming from the oven at temperatures slightly below 100 ° C will have moisture of about 40% at the centre. The crust will be hotter, but much drier (12% moisture) and cools rapidly. During cooling, moisture moves from the centre of the loaf outward towards the crust and then into the ambient atmosphere. If the moisture content of the crust rises greatly, the result is the formation of leathery and tough texture resulting in loss of crispness and attractive appearance. On aging, the breadcrumb becomes more firm and opaque and the water absorbing capacity is reduced (due to changes in amylopectin of the starch). The maximum staling rate occurs at 4 ° C, and reheating reverses this process.

Conventional packages

In the organized sector bakeries, bread is sliced and wrapped on automatic machines while in unorganised sector, it is sold in relatively cheaper wraps such as poster paper, newspaper, etc. which result in excessive moisture loss, stickiness, and even contamination of the product by surface printing ink and tainting.

The standards of weight and measures act (SWMA) stipulate that bread should be sold in weights of 100, 200, 400, 500 and 1200 grams and hence generally bread is sold in waxed sulphite paper which carries printed information regarding the brand, type and weight etc. Waxed papers used for bread and bun packaging is generally made of a base paper made of bleached sulphite pulp with coating of wax blend comprising paraffin wax, microcrystalline wax and hot melts.

Loose wrap: Loosely wrapped unsealed packs generally obtained by using one side waxed paper.

Primary pack (Regular): Individual pack made by using both sides waxed, printed paper having play value and to be dispensed as a unit.

Secondary pack: A pack in which a product is pre-packed in a carton and subsequently over wraped with protective waxed wrappers.

Types of waxed papers:

Type 1: Both sides waxed, bleached TiO_2 loaded paper, generally used for packaging bread.

Type 2: One side waxed, bleached TiO_2 loaded paper, generally used for loose wraps of biscuits.

Type 3: Both sides waxed, bleached, TiO_2 loaded paper, generally used for primary packs (regular) of biscuits.

Type 4: Both sides waxed, bleached, greaseproof paper, generally used as inner wrapped in secondary packs.

Type 5: Both sides waxed, bleached paper, and generally used as outer wrapper in secondary packs.

Other requirements:

Fixed paper: The material shall be uniformly coated with paraffin wax or its blends. They shall be uniform in thickness and should not rupture on folding or twisting. The burst factor, i.e., bursting strength to basis weight ratio shall be 13 (minimum) for all types. The tear factor shall be minimum of 33 in machine direction and 40 in cross direction.

The wax used shall have minimum melting point of 60° C.

Requirements for waxed paper for bread:

Type	***Wax content % by mass min.***	***WVTR, g/m^2 24 hr at (38 + 1)°C and (90+2)% RH, max.***
Type 1	38	8
Type 2	36	10
Type 3	50	5
Type 4	40	5
Type 5	40	10

The chemical requirements for waxed papers are:

Characteristics	Requirements
Arsenic (ppm, max).	2
Total copper (ppm, max).	30
Water soluble copper (ppm, max).	10
Total iron (ppm, max).	70
Water soluble iron (ppm, max).	15
Lead (ppm, max).	20

Newer packages

Apart from waxed paper, cellophane was the next widely used packaging material for bakery industry. Cellophanes are a range of materials with good clarity, printability, stiffness and ability to run well on machines, with varying protective properties. They can provide optimum WVTR and have good odour and gas barrier properties. The search for lower cost, packaging materials resulted in selection of polyolefin plastics, LDPF, HDPE, HMHDPE, CPP and BOPP.

Low-density polyethylene film is soft, mostly transparent and has low WVTR and can provide good heat seal. Its limp nature which makes it difficult to machine on over wrap equipments has hampered its widespread use, but preformed bags, though costlier are used successfully as convenient consumer bags for bread and buns. One advantage of such bags is the reclosure facility with thread, tip-top closures and plastic clips. Bread bags are mostly made from 25 micron film which have a WVTR of 14-15 g/m^2 24 hr at 38°C condition and in thickness they are quite economical.

HDPE films having greater mechanical strength than LDPE and also having better barrier properties can be formed into bags on thinner gauges. This can offset to some extent the higher cost of plastic packages. Polypropylene, due to its greater clarity, rigidity and good machinability is being increasing used. PP is found to be structurally adequate at thin gauges and hence are more economical.

Newer developments in the field of bread packaging include certain process modifications in the product to provide longer shelf life and modified and controlled atmospheric packaging using carbon dioxide. For these applications, better barrier materials comprising coated PP, polyamide, polyester (plain and metallised) and coextruded films have to be used.

2.11 SUMMARY

Several bread making processes are available around the world and great varieties of breads are produced using these processes. Bread making processes have been modified to suit modern and fast processing of wheat flour into bread. The earlier processes had requirements of long fermentation and large space requirements. The recently developed processes are no time to minimum time processes, which are fast, labour and space effective. The main differences between individual and groups of bread making processes are normally associated with mixing and kneading, air incorporation, and the creation and development of the gluten structure. Major bread making processes are long fermentation process, rapid processes, mechanical dough development process, microwave process and frozen dough process.

2.12 KEY WORDS

Rapid processes: In these bread making methods a very short or no period of bulk fermentation is given to the dough after mixing and before dividing.

Mechanical dough development process: In this process of bread making primary function of mixing is to impart significant quantities of energy to facilitate dough development, and the dough moves without delay from mixer to divider. The dough is developed by high level of energy imparted at the stage of mixing.

Straight dough bulk fermentation process: The dough is fermented in bulk. This is the most traditional and most 'natural' of the bread making process.

Chorleywood bread process (CBP): Mixing and dough development takes place in a single operation lasting between 2 and 5 minute at a fixed energy input of 11Wh/kg of dough.

Loose wrap: Loosely wrapped unsealed packs generally obtained by using one side waxed paper.

Primary pack (Regular): Individual pack made by using both sides waxed, printed paper having play value and to be dispensed as a unit.

Secondary pack: A pack in which a product is pre-packed in a carton and subsequently over wrapped with protective waxed wrappers.

2.13 SELF ASSESSMENT QUESTIONS

1. Discuss major functions of breadmaking process.

2. Classify major breadmaking processes and indicate main differentiation between them.

3. What are the special features of straight dough process?

4. Describe process of sponge and dough method.

5. How dough is developed in Chorleywood Bread Process? What are the special features of this method of breadmaking?

6. What are the major advantages and limitations of various breadmaking processes?

7. Indicate main functions of a package. What should be the properties of an ideal bread package?

8. Suggest some new packages for stability of bread during storage.

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PGDBST- 05 **B.S.Khatkar**

UNIT III: VARIETY BREAD PRODUCTS

STRUCTURE

3.0 OBJECTIVES

This unit is designed to explain the formulations and manufacturing process of various types of breads. It also discusses the methods of assessment of bread quality.

3.1 INTRODUCTION

Formulation, production, packaging and distribution of maida or white bread have been standardized. Although the white bread attained great prominence in the up to 1960s, its consumption in the western countries has started decreasing lately. On the other hand, variety bread products have picked up a market share because they have a superior taste of their own and have desirable sensory and nutritional qualities. These variety breads have been developed through a combination of factors. Variety bread offers consumer's choice of flavour and textures. The choices are amplified by consumer's perceptions of real or fancied nutritional benefits associated with the type of breads. Although the white bread is one of the major types consumed in our country, there is a great scope for introducing variety breads with the objective of adding interest to the diet and to avoid the monotony of eating of only one type of bread. Although in India only white pan bread is produced but in the western countries particularly Europe, more than 250 types of variety breads are available. In India hardly one dozen types of biscuits are available in the market but in the western countries more than 1000 types of biscuits compete for space on the grocer's shelves.

3.2 MULTIGRAIN BREAD

Multigain breads are made with wheat flour and cereal grains as well as oil seeds. Many types of multigrain breads have been made to sustain consumer interest in number of developed countries. The grains and vegetables that have been used include corn, flax, millet, triticale, buckwheat, barley, oats, alfalfa, soy, potato, rye, rice and sauerkraut. Utilization of whole wheat and non-wheat cereal grains particularly oat, barley and rye will not only provide significant therapeutic benefits to our society but also will help to meet the growing food demand of our country, because these coarse cereal grains are presently being used as animal and poultry feed. Oat and barley contain some compounds including β-glucan that are credited with serum cholesterol reduction.

These materials are used as flours, grits or as whole-grains. The multigrain bread doughs are similar to rye doughs and are mixed for relatively shorter period or at slower mixing speeds because of high amounts of non-gluten materials. Dough temperatures are kept relatively low and the fermentation times are shorter compared with those for white pan bread dough. Multigrain breads are typically dense products with a coarse crumb structure.

3.3 HIGH FIBER BREAD

In view of the importance of dietary fiber in reducing diet related diseases, increased emphasis is being laid on high fiber products. Recently tremendous changes in the dietary patterns of high-income group have been witnessed in our country. Due to the fast moving lifestyle, this section of our population has become habitual of taking fibre depleted energy concentrated so called ‘modern foods’ like hot dogs, bergers, pizzas, sweets, ice-creams, soft drinks, white bread, cakes, meat and meat products, fried foods, etc. The regular consumption of these refined foods has resulted in the prevalence of a number of diet related diseases, such as obesity, high blood pressure, diabetes, cancer of colon, gastrointestinal disease and cardiovascular disease. These people demand special types of dietary foods to be formulated containing higher dietary fibre contents. Dietary fibre helps to alleviate such diseases.

The sources of fibers include wheat bran, corn bran, rice bran, rye bran, barley bran, triticale bran and oat bran. However, the beneficial effect of bran has been found only in coarse brans. Among the above sources of bran, barley and oat brans have been proved to reduce the level cholesterol in the human body. This bran has also been reported to benefit the diabetic patients in delaying rise in glucose level. High fiber bread has also been found to overcome the problem of constipation. Rye bran reduces the concentration of certain tumor promoters, mutagens and also certain bacterial enzymes thought to play a role in colon cancer. It is therefore important to explore the possibility of developing acceptable bakery products using whole wheat, non-wheat cereal grains and their brans.

In preparation of these products bran could be used at levels up to 30% with minimum adverse effect. Use of bran, increases the water absorption and reduces fermentation time of dough. Use of sponge and dough method and incorporating surfactants like sodium stearoyl lactylate however, improves quality of bread. Higher level of oxidants and yeast further softens the texture. In addition to using bran, gums like guar, karaya, xanthan, CMC etc. could be used as a source of dietary fiber.

3.4 CRACKD WHEAT BREAD

Adding about 15% cracked wheat in the formulation makes this bread. Even clear flours could be used. It is better to soak cracked wheat in water for 2-3 hr.

Typical recipe	**(%)**
Clear flour	72
White flour	14
Cracked wheat	14
Water	64
Salt	2.0
Sugar	5.0
Yeast	2.5
Fat	2.0

3.5 SOUR DOUGH BREAD

Sour dough breads and rolls have become popular in recent years particularly in European countries. These breads resemble white pan or hearth breads in formulation and overall quality except that these are acidic in taste. Mostly, starter is used in the initial stage, which is taken from ripe sour. It can also be produced by spontaneous fermentation process by bacteria present in flour and air. Generally, rye bread is prepared by sourdough process.

Distinctive acid, flavor, thick and hard crust open uneven grain, and chewy crumb texture characterize sourdough bread. Boiling treated potatoes and mixing high protein flour in to the potato water to form a batter can develop new sour starter. This is fermented till gas formation stops and mixed with flour to form stiff dough and again fermented to double its size. This starter could be used at 10-15% level.

The sour dough sponge can be made nearly 8 hr or every day by mixing 40% at previous starter with 40% of high protein flour and 20% water and holding the sponge for 8 hr at 27°C. At the end of the period, the pH value drops from 4.4 to 3.9. Mixing 10-20% parts of starter sponge, 100 parts of flour, 60 parts water, 2 parts of salt makes the dough. The dough is given a flour time of 1 hr, divided and moulded and gives a proof time of 6-8 hr when the pH drops from 5.3 to 3.9. Hearth bread is baked for 45-50 min. at 190-200°C with steam at initial stages.

3.6 MILK BREAD

Milk bread should contain at least 6.0% milk solids. Milk solids could be added as skimmed or whole milk solids, or milk, which is sterilized, or condensed milk when preparing milk powder, the following points is to be considered.

1. Fat content in the milk

2. Lactose unfermented by yeast. Hence, adds to colour and sweetness.

3. Protein of milk has a volume depressing effect due to the presence of free sulfhydryl groups, which acts as reducing agents.

4. Milk improves the nutritional quality.

5. Incorporation of higher amounts of oxidants helps in overcoming the deleterious effect of milk protein.

3.7 COMPOSITE FLOUR BREAD

Considerable proportion of bread produced in Germany and other European countries includes mixture of wheat and rye. The concept of composite flour was developed (i) to utilize indigenously available non-wheat cereals, tubers, millets, etc. (ii) to improve the nutritional quality by using protein rich raw materials (iii) to extend the wheat availability (iv) to produce products with different flavour/taste profiles.

Refined flours from maize, jowar, barley, tapioca, potato or any other cereal or tuber flours could be used in bread. These flours do not contain gluten and hence their incorporation into wheat flour naturally bring down the gluten content and hence the quality of bread. However, up to 5% of the above flours could be incorporated in wheat flour without any adverse effect on the quality. Use of higher levels, however, reduces water absorption, loaf volume and harder texture of bread. Even up to 20-25% level of these flours could be used, but the resultant product becomes rough and lacks other desired quality parameters. Attempts have also been made to over come the deleterious effects of using composite flour bread, by altering the processing conditions, changing the recipe, and use of improvers or additives.

Mechanical dough development by high speed mixing or by sheeting and chemical dough development have been found to be best suited for composite flour breads. Use of higher levels of oxidants and addition of emulsifiers or surfactants improve considerably the quality of bread. The formulation of non-wheat flour that could be used depends on the quality of wheat flours. It is normal to expect lower mixing time and fermentation time for composite flours. Calcium stearoyl lactylate or sodium stearoyl lactylate has been found to be the best surfactants that could be used in such breads. Recently, emphasis is being laid to the use of millet or legume flours in bread manufacture. They would help in producing newer varieties of products with improved nutritional quality and taste.

3.8 HIGH PROTEIN BREAD

Wheat flour has a good carrying capacity and hence it could be fortified with respect to calories, protein, salt, carbohydrates, vitamins and minerals required for special target groups. There is a greater scope to produce high protein breads using protein rich oilseed meals. Normal white pan bread contains only 6 to 10% proteins. Any of the defatted oilseed meals contain protein ranging from 40-60%.

High protein material increases the water absorption capacity and also improves the keeping quality. The oilseed meals that could be used are groundnut flour, Soya flour, cottonseed meals, sunflower meal, sesame flour, etc. Uses of these protein sources require alteration in the processing methods, and recipe. Mechanical or chemical dough development is found to be better for high protein breads. Even normal method of sponge and dough, could be used but the sponge fermentation time has to be considerably reduced. Use of surfactants like SSL is reported to improve the quality because of its strengthening effect on wheat gluten.

Full fat soy flour produce bread with acceptable volume, texture, flavour and overall quality up to 15 to 20% level of incorporation due to presence of lecithin and glyco-lipids.

3.9 WHEAT GERM BREAD

Wheat germ bread must contain at least 10% of germ. Wheat germ, which is a by-product of flour milling, is nutritionally many superiors to other protein sources.

It contains as high as 30% protein of quality similar to the protein of eggs or milk. It is also a rich source of vitamins and minerals and richest known source of tocopherol. It has been found that toasting of germ not only improves taste and colour but also the keeping quality. Fifteen per cent of toasted germ powder could be used in bread with minimum effect on the quality. The taste of such bread is superiors to those made with oil seed meals which normally impart nutty flavour.

3.10 SUGAR FREE BREAD

In sugar free breads, sugar is replaced with enzyme active flour (2.0%). Formulation of sugar free bread is given below:

Ingredients	(%)
Wheat flour	100
Yeast	2 g
Salt	15
Malt	2
Ascorbic acid	100 ppm

The taste of such breads will be bland. Hence, other natural sugars like sorbitol could be used. Sorbitol has sweetness of 60% of sucrose. Hence, diabetic patients could use breads made with sorbitol and the quality of bread compares well with normal bread.

3.11 LOW CALORIE BREAD

Low calorie breads are made using cereal brans and fat substitutes. Sucrose esters have been found to be a good substitute for fat. The demand for low fat/low calorie/light foods is increasing considerably in other parts of the world. Using proper surfactant maltodextrin or sucrose ester makes low or no fat bakery products. The other ingredients that could replace fat are modified starches, dextrins, fibers, enzymes and emulsifiers.

3.12 LOW SALT BREAD

Salt is an essential ingredient in bakery products. It has stabilizing influence on fermentation and hence production of carbon dioxide and flavour compounds. It also strengthens the gluten and hence the dough incorporation of salt improves the loaf volume, colour and textural parameters in addition to the taste and flavour of bakery products. Average dietary intake of salt at levels of 10-12 g/day is reported to be harmful to those with a tendency for hypertension.

The balance of various minerals in the body is essential for proper physiological functions. Potassium and magnesium have been reported to counteract the harmful effect of sodium in hypertensive cases. Sodium ion helps in association of gluten proteins and hence strengthens the dough and reduces the water absorption capacity.

Complete replacement of sodium chloride has no effect on the dough rheology, but has an effect in the bread quality with respect to taste. Such bread has an unpleasant after taste. However, it is found that 50 per cent of the sodium chloride could be replaced with potassium or magnesium chloride without perceptible change in the taste of bread. In India, salt substitute is commercially available and that could be used in bread or biscuits. Even rock salt containing low sodium could be used as a salt substitute without any effect on the dough characteristics and quality of bakery products.

Sweet and salt biscuits also can be made using salt substitutes. It is also advisable to replace chemical leavening agent-sodium bicarbonate with potassium bicarbonate to reduce the sodium content.

3.13 GLUTEN FREE BREAD

A small segment of population suffers from dietary wheat intolerance, which includes disturbances known as celiac disease. The symptoms may include cramps, diarrhea etc. and the responsible factor has been found to be gliadin. Using wheat starch or any other non-wheat flours and gluten substitutes consisting of pre-gelatinized starch, guar gum and carboxyl methylcellulose could make gluten free breads. Use of emulsifiers like mono and di-glycerides and sodium stearoyl lactylate have been found to be beneficial in improving the quality of bread. As a protein source soya flour could be incorporated in such breads.

3.14 MISCELLANEOUS VARIETY BREADS

The less popular variety breads include raisin, cinnamon raisin, oatmeal, fruit, hearth and rye bread. A brief description of these varieties of bread is given below:

Fruit breads

Raisin bread is the most important kind of fruit bread in the western countries. In India there is a greater potential for using fruit bits popularly known as 'tutifruiti' in bread and bun formulations. Stronger flour is required in order to carry the raisins, tutifruiti to maintain good loaf volume. Yeasts levels are relatively high compared with those for making white pan bread, because raisins contain acids that inhibit fermentation. Sugar can be replaced with honey as sweetener but cost of honey increases the cost of product. Some premium raisin/tutifruiti breads can also be made with added whole-eggs.

Health Breads

In recent years many new bakery products have become popular in different parts of the world. They are high fiber breads, low calorie bread, salt reduced breads and high calcium breads. In India, though high fiber breads may not have much demand at the moment, there is a considerable demand for low calories, or sugar free breads particularly needed for obese persons of diabetic patients.

Brown bread

Brown bread is normally made by mixing maida and whole wheat flour in the ratio of 50:50 or higher whole wheat in maida. The processing conditions are the same as whole wheat bread. The volume of brown bread is generally better than whole wheat bread. Incorporation of malt extract or brown sugar improves colour and flavour of brown bread.

Hearth breads

Hearth breads are baked on hearth or a metallic plate. They are normally made by lean recipe. French, Vienna and Italian breads are the popular hearth breads. Compared to normal breads, hearth breads have hard thick crust and open texture. The typical formulation of hearth bread is as follows:

Ingredients	**(%)**
Flour	40-20
Water	55-58
Salt	2.0
Sugar	1-3
Fat	0-2
Yeast	Optional
Milk	0-2

The processing operations are similar to pan breads. The Italian and Vienna breads also belong to the category of hearth breads made using lean formula. Only differences are the size and shape and number and types of cut given in the surface before baking. It has a fine golden town crisp crust. The use of milk and short dough fermentation is contributing factor for its popularity. It could be made either straight or by sponge and dough method. The cut is given along the length at the center.

Rye bread

Rye bread is produced in different shapes, sizes and taste to suit the palate of consumers. The main ingredients used are wheat flour rye flour, water, yeast and salt. Other ingredients may include malt, sourdough, color etc. Rye flour can be obtained in to three major groups white, medium and dark. They differ in ash content. Rye flour offers more favourable acid environment for yeast than white wheat flour. Its levels of sugars, dextrins are somewhat higher. In addition, rye flour has higher alpha amylase activity and lower active fermentation. Acid flavour in rye bread can be imparted by using sours that contains blends of lactic acid or acetic acid, in various ratios often combined with dried yeast and bacterial cultures with flour as a carrier. One can also prepare sourdough to meet the daily requirement. Prepared sours are available, commercially and used at 5-10% levels. Sour cultures are used in sponge stage. Sourdoughs are essentially rye sponges that are fermented by hetero and homo fermentative bacteria Lactobacillus. Sourdough cultures are prepared in three stages in which small quantity of rich sourdough is used as a starter. The acid production depends on consistency of the dough. This is again transformed in to full sour by mixing with rye flour and water 10% and fermenting at 30-30°C, which favours activation of lactobacillus and yeast responsible for lactic acid. This is used at 40-50% level in sourdough. Total time required is 25-32 hr.

Bread varieties with different shapes

Bread varieties can be prepared by changing the shape either by changing the shape of the dough or by rolling the dough to different shapes such as split tin, sandwich, and long tins. Rolls can be made by number of shapes by taking 1 to 5 long dough pieces rolled in to ropes ad then twisting it in to different shapes. These rolls are placed on a tray and proofed and baked. However, like French bread, containing the proofed dough with egg milk or sugar solution is necessary to impart color.

3.15 FORMULATION AND PROCESSING OF VARIETY BREADS

Some variety bread products that do not fit into major categories are commercially important in the western countries. Among these English muffin production has increased considerably in the last 10 years in the North American markets. The product is made from white yeasted dough i.e. notable for its soft consistency (about 80% absorption). The muffins are grilled over a griddle rather than baked in an oven. High protein breads have failed to win consumer acceptance in number of countries although in India soya fortified bread is being made by number of bakeries for school lunch feeding programmes. Hard and soft rolls have become increasingly popular and high-speed equipment has been developed for their production on the commercial scale in the western countries. The variety-baked products are generally produced on a semi-commercial basis. The ingredient costs are usually high, the processing equipment also requires special designs to suit the variety and the shelf life of these products is usually limited which may cause distribution problems for the bakers. These factors indicate that the costs of producing variety breads are greater than the costs of producing conventional white pan breads. At the same time, however, variety breads are more profitable on a unit basis as they yield 40-70 per cent higher return that the white pan bread. In the production of variety breads, the formulations include special ingredients such as grains, malt, bran, milk, sourdough culture, wheat germ, etc in addition to the regular formula ingredients. The processing includes weighing, mixing, fermentation, punching, moulding, proving and baking as usual with minor modifications to suit a specialty product formulation.

3.16 ASSESSMENT OF BREAD QUALITY

An expert panel generally assesses quality of bread, which is a subjective judgement. Objective methods have also been evolved to judge the quality of bread. The techniques for assessing bread quality usually fall into three broad categories: external, internal and texture/eating quality.

External quality attributes of bread

The external quality attributes include product dimensions, volume, appearance, colour and crust characteristics. The critical dimensions for most bread are their length and height, with breadth being of lesser importance. Devices for measuring product dimensions off-line can be simple and include graduated rulers and tapes. It is possible to measure product height and shape on-line using image analysis techniques. Measurement of height will often be used together with width as a basis for an estimation of volume where the product shape makes such estimates meaningful, for example with rectangular pan breads.

The most common method of assessing whole bread volume is by using a seed displacement method. The apparatus comprises a container of known volume, which has previously been calibrated with a suitable seed, usually rapeseed or pearl barley, into which the product is introduced. The seed is reintroduced and the product displaces a volume of seed equivalent to its own volume. It is important to keep such apparatus regularly calibrated with suitable ‘dummy’ products of known volume since the bulk density of seeds may change with time.

The external appearance of the product quite often is a major factor, which attracts the consumer. The consumers prefer golden brown crust. The presence of undesirable surface blemishes reduces the loaf quality score.

Internal quality attributes of bread

Internal quality attributes of bread are usually refers to size, number and distribution of cells in the crumb, the crumb colour and any major quality defects, such as unwanted holes of dense patches, visible in a cross-section of the product.

Texture/eating quality of flavour

Texture and eating quality are important properties of bread products and are different from one another. Crumb softness or firmness is the texture property, which has attracted most attention in bread assessment because of its close association with human perception of freshness. The bread internal quality may be judged by squeezing the loaf. A fresh loaf will be softer and spring back as the squeezing is withdrawn. Texture analyzer can also judge freshness of crumb also.

3.17 SUMMARY

Formulation, production, packaging and distribution of maida or white bread have been standardized. Although the white bread attained great prominence up to 1960s, its consumption in the western countries has started decreasing lately. On the other hand, variety bread products have picked up a market share because they have a superior taste of their own and have desirable sensory and nutritional qualities. These variety breads have been developed through a combination of factors. Variety bread offers consumer's choice of flavour and textures. The choices are amplified by consumer's perceptions of real or fancied nutritional benefits associated with the type of breads. Although the white bread is one of the major types consumed in our country, there is a great scope for introducing variety breads with the objective of adding interest to the diet and to avoid the monotony of eating of only one type of bread. A variety of bread can be produced to satisfy the emerging culinary needs of the consumer. Various breads which can find acceptability include multigrain, high fiber, sour, gluten free, sugar free, low salt, high protein and wheat germ bread. An expert panel generally assesses quality of bread, which is a subjective judgment. Objective methods have also been evolved to judge the quality of bread. The techniques for assessing bread quality usually fall into three broad categories: external, internal and texture/eating quality.

3.18 KEY WORDS

Sour dough bread: Bread that is produced using bacterial culture rather than yeast culture. The sour dough bread is more acidic than the yeast raised bread.

High fiber bread: The bread prepared from whole wheat flour or maida plus wheat bran or maida plus whole grain flour from other cereal grains such as rye, oat, etc. The bran and whole grains are considered rich source of fiber. High fiber bread has been credited with cholesterol lowering effects and it also keeps the consumer health for many reasons.

Sugar free bread: In sugar free breads, sugar is replaced with enzyme active flour (2.0%). The taste of such breads will be bland. Hence, other natural sugars like sorbitol could be used. Sorbitol has sweetness of 60% of sucrose. Hence, diabetic patients could use breads made with sorbitol and the quality of bread compares well with normal bread.

Composite flour bread: Refined flours from maize, jowar, barley, tapioca, potato or any other cereal or tuber flours could be used to produce composite flour bread, that is, bread made using flours obtained from many cereal grains.

Gluten free bread: Bread prepared from a formulation except wheat gluten. A small segment of population suffers from dietary wheat gluten intolerance, which includes disturbances known as celiac disease. The symptoms may include cramps, diarrhea etc. and the responsible factor has been found to be gliadin. Using wheat starch or any other non-wheat flours and gluten substitutes consisting of pre-gelatinized starch, guar gum and carboxyl methylcellulose could make gluten free breads.

3.19. SELF ASSESSMENT QUESTIONS

1. Why variety breads are required?
2. Which grains are most suited for multigrain breads? What is their importance?
3. Which fiber sources are used for high fiber breads? What are their nutritional benefits?
4. How does sourdough differ from white pan bread?
5. Why gluten free bread is produced? Does it match in quality with white pan bread?
6. How bread quality is assessed?

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PGDBST- 05 **B.S.Khatkar**

UNIT IV: BREAD SPOILAGE AND STALING

STRUCTURE

4.0 OBJECTIVES

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

- Microbial spoilage of bread
- Bread staling
- Factors affecting rate of staling
- Approaches to counteract bread staling

4.1 INTRODUCTION

In commercial bakery units, the shelf life of bread is linked to their profitability and reputation in the market. Bread staling, development of rope and molds are the major problems of bread during storage. Such changes make the bread unfit for human consumption and bakers suffer in reputation and economically too. In this lesson efforts are made to explain factors influencing shelf life of bread and suitable measures are suggested to extend the period during which bread remained fit for human consumption.

4.2 MICROBIAL SPOILAGE OF BREAD

Persistent problem that every baker faces in marketing of his bakery products is that of microbial spoilage caused mainly by mold growth and occasionally by bacterial contamination. Mold growth may occur at any place on the baked product while bacterial spoilage generally occurs in the icings, and fillings. Because of this variability, several materials have been introduced to best cope with these problems and it is advisable to learn what they are and how they can be used to greatest advantage.

4.2.1 ROPE DEVELOPMENT IN BREAD

In baking, rope is a bread disease. The presence of rope in bread results in breaking down of starch and protein, producing a discolored and sticky condition in the crumb which is accompanied by an odour similar to the odour of a rotten pineapple. The ropiness generally appears in bread 12 to 36 hrs after baking and mainly during summer months when ambient temperature reaches 35°C or higher.

Rope in bread is caused directly by bacteria known as *Bacillus measentericus*. The rope spores are present in the air and can also be carried by the particle of dust. This, including insanitary conditions in bakery, can infect the bakery raw materials and eventually cause ropiness in the bread.

(a) Detection of rope in the bread

There are four physical signs, which either singularly or jointly should be used for detecting rope in bread. These signs are:

(i) Unpleasant odour and taste of the loaf resembling to an over-riped pineapple.

(ii) Gradual darkening of the crumb which eventually becomes brown.

(iii) Stickiness of the crumb due to the presence of slimy spots on it.

(iv) A peculiar reddish or foxy dark colour of the crust.

(b) Means to check ropiness in bread

(i) The development of rope in bread can be controlled by acidifying the dough. Acidity can be produced by vinegar, acetic acid or by incorporating any harmless organic acid or a suitable acidic salt in the dough. Since these materials slow down fermentation, they should be added as near the end of the progress as possible during dough/fermentation.

(ii) By making stiffer dough by reducing the water a little bit.

(iii) Reduce the amount of sugar in the dough.

(iv) Use bits of 'Old doughs' which will have more acidity.

(v) Use slightly cooler oven and bake a little longer and

(vi) Cool bread as rapidly as possible before wrapping.

(vi) Other measures will include general cleanliness of the bakery premises, maintenance of a clean storage area for the raw materials, keeping the dough on cooler side maintaining healthy, vigorous fermentation conditions, proper and thorough baking; proper cooling of bread before wrapping and maintenance of cleanliness in the finished product storage area.

4.2.2 MOLD GROWTH IN BREAD

Bread if kept under warm or moist conditions will develop thread like whiskers, which are generally due to the presence of mold. The colour of these molds can be brown, red, orange, yellow, green blue, pink, white or black. Air, flies or insects can carry mold spores. Mold spores usually settle outside of the bread, therefore, mold growth is noticeable on the exterior surface. Most commonly found molds in bread are of the Aspergillus, Penicillium, Rhizopus and Mucor. None of which is disease producing microorganisms. The slicer blades, if kept unclean, are source of mold contamination of sliced bread.

a) Means to check mold growth in bread

Acetic acid and propionates are two most commonly used mold inhibitors. Both of these chemicals are more effective if the dough is acidic. Dough acidity can be increased by the use of ammonium chloride in the dough which performs two functions. Firstly, it acts as a great food for vigorous fermentation and secondly it increases the acidity of the dough. As a starling level, 30g of ammonium chloride is sufficient for 100 kg of flour (i.e.. 0.03% on flour basis).

Acetic acid and calcium propionate should be used at a starting level of 0.20% on flour basis. As both of acetic acid and calcium propionate slows down fermentation, they should be mixed as near to the end of the process as possible or the quantity of yeast has to be increased.

Because the moldiness of bread is generally caused due to insanitary conditions of slicer blades, packing materials and bakery shop floor; effort should be made to eliminate such conditions. The slicer blades should be cleaned with dilute acidic acid frequently. Moreover, bun production should be encouraged in our country, as these types of bakery products have longer mold free shelf life. Another approach could be use of the bread as unsliced one, but serrated bread knife should be available in the market, which people could buy and slice the bread as and when necessary. The unsliced bread has been shown to have longer shelf life.

Certain other protective measures such as general cleanliness in the bakery, proper baking, cooling, wrapping of bread, and use of filtered and washed air in the bakery for cooling of bread also reduces the chances of mold growth in sliced bread.

4.2.3 YEAST SPOILAGE

Yeast spoilage of bread is rare, but it may occur sometime by wild yeast in long fermentation process. Yeast, like mould does not survive the baking process, it may contaminate bread during cooling and slicing. Yeast contamination in bread plant occurs mainly through dirty equipments and infected sugars. Fermentative and filamentous yeast are held responsible for bread spoilage. Filamentous yeast is known as ‘chalk mould’ because they form a white, spreading growth on bread surface which can easily be confused with mould. Use of ethanol spray can prevent yeast growth in bread.

4.3 BREAD STALING

Bread staling, broadly, includes all changes, except microbial that occur in bread after baking. Changes occur in both crumb and crust of the bread, however, crumb firmness is more correlated with bread staling. Other changes such as loss of flavour, decrease in water absorption capacity, amount of soluble starch, enzyme susceptibility of the starch, increase in starch crystallinity and opacity are also associated with bread staling. All these changes affect to a large extent, the palatability of bread and hence consumer's acceptance.

Bread filming is virtually arrested at temperature of -20^{0}C or less, and at -2°C the finning rate is at its maximum. A 60-100ºC, it is possible to reverse most of the stale character of bread due to the heat reversible character of starch retrogradation.

4.3.1 CRUST STALING

The crust of fresh bread is crisp, brittle and somewhat dry. On staling it becomes soft, tough and leathery. This is caused due to migration of moisture from the moist center crumb to the crust. The hygroscopic crust readily absorbs moisture which diffuses outwards and becomes soft and leathery. The excess humidity, above 80% R.H.in the bread store is also undesirable.

Preventing the evaporation of water from crust to the atmosphere can inhibit the staling rate of crust. The bread if packed in the moisture proof wax coated paper or film, which does not permit the moisture from interior of the loaf to pass through crust into the atmosphere, stays fresh for longer time.

4.3.2 CRUMB STALING

The outstanding work on bread staling by a Dutch Scientist, shows that the crumb staling depends on changes in the starch to a certain extent. The proteins take up the water released by starch. He proposed the change in starch fraction to be the main reason of crumb staling. The starch cells absorb more water when bread is fresh and have alpha-pattern which on lowering of temperature, changes slowly to the beta pattern, which holds less water. As the crumb of bread stales it becomes drier, less elastic, crumbly and harsh textured. It also looses the fresh flavour and aroma.

4.3.3 CAUSES OF STALING

The moisture migration, change in the structure of starch and retrogradation due to various physical factor, are the major causes of the staling. Staling is caused by changes in moisture content and starch structure during storage of bread. The starch, which has been gelatinized during baking holds the moisture contained in bread, and when the loaf comes out of the oven, the gelatinized starch that is distributed throughout the loaf contains the maximum amount of moisture. Some of the moisture does disappear from the loaf by evaporation as the bread cools, but other constituents of the loaf, especially the coagulated gluten, absorb some of the moisture contained in the gelatinized starch. The result of this migration of moisture from the starch to the gluten is claimed to be largely responsible for the development of staleness in bread.

Ethanol reacts with starch and prevents its retrogradation, thereby inhibiting the bread staling process. The ratio of starch to protein in dough is critical in determining the rate of staling.

4.3.4 FACTORS AFFECTING RATE OF STALING AND DIFFERENT APPROACHES TO COUNTERACT STALING (STALING INHIBITORS).

At the time of the London meeting in 1968, it was well accepted that bread crumb firming was not fundamentally the result of moisture evaporation, starch crystallization or retrogradation as a principle causative factor, even though they have some influence over it. The following characteristic changes take place during the staling of bread.

(i) Change in taste and aroma

(ii) Increased hardness of crumb

(iii) Increased opacity of crumb

(iv) Increased crumbliness of crumb

(v) Increased starch crystallization of crumb

(vi) Decreased absorptive capacity of crumb

(vii) Decreased susceptibility of crumb to amylases

Through the years, the role of various factors have been investigated and reported to influence the rate of bread staling. It must be assumed that all ingredients and processing conditions will have some influence. This assumption can best be appreciated by reviewing what has been reported and these factors should be taken into account with the aim of retarding or even eliminating the staling of bread.

1. Influence of protein level

Staling proceeds more rapidly in white bread than in whole wheat and rye bread. This is probably due to the fact that the whole wheat and rye breads are generally higher in protein and pentosans content than normal white bread. Pentosans and proteins retain more bound moisture in the bread and hence the bread retains freshness for longer lime. Moreover, increase in protein levels result in increased loaf volume. The softness may be a function of increase in loaf value. A loaf with comparatively high protein and low starch content than the normal bread will retain freshness for longer time.

The protein quality also plays an important role in the rate of staling of bread. The bread from soft wheat flour containing 10-15% protein stale more rapidly than semi hard wheat flour containing 9.6% protein. Gluten moisture plays significant role in crumb firming with time, involving irreversible modification of the water structure of gluten and loss of moisture from gluten to the crust and package.

2. Influence of carbohydrate type and amount

2 to 4% added sugar slightly slows down crumb staling. Maltose syrup was found to be more effective followed by glucose syrup, dextrin, beet sugar, maltose and glucose. The effectiveness of sugars in reducing firmness follows the order ribose > sucrose > glucose. Addition of higher Oligosaccharides appeared to accelerate breadcrumb staling. Oligosaccharide serves as aggregating agents of starch and promotes starch retrogradation. Bread baked with Karaya gum shows higher water absorption and higher crumbs moisture than the control bread.

3. Influence of pentosans

The pentosans have a very high water binding capacity and bind about 10 times the weight of water than their own weight. This higher degree of water binding of pentosans, probably, helps improving the freshness of bread. Pentosans have a definite effect in slowing down the firming of starch gels, the water insoluble pentosans having more pronounced effect than those of water soluble pentosans.

4. Influence of whole wheat flour

Bread made from whole wheat flour retains freshness for a longer time than the white bread. This might primarily be due to the higher moisture content of whole wheat bread than the white bread. In addition to anti-staling effect, the whole wheat bread is more nutritional because it retains the bran, aleurone layer and germ of wheat kernel. Moreover, the whole wheat bread is more nearer to the chapati in composition and taste. Therefore, looking at these advantages of whole wheat flour, the whole wheat bread needs to be commercialized to get the benefits of better nutrition, improved freshness and higher yield of bread.

5. Influence of shortening

Shortening or fat is one of the most essential ingredients in bread making, added to facilitate dough handling and processing to improve loaf volume, crumb grain, consumer acceptance and to prolong the shelf-life. Two mechanisms of shortening effect, viz. chemical and physical have been suggested. The chemical effect involving lipid oxidation was considered least significant in bread making. The physical effects include lubrication, sealing, foam formation, involvement of hydrogen and hydrophobia bonds and delayed CO_2 release. Rate of CO_2 release is faster in dough baked without shortening than in dough with shortening. Fat present in dough increased gas retention in the initial stages of rapid expansion. The final loaf volume depends on the permeability of the dough to CO_2 in earlier stages of baking. Physical mechanism accounts for the increased loaf volume on adding shortening to dough. Increased loaf volume seems to be responsible for improving softness of bread. The level of shortening influences significantly the staling of bread after 20 h of storage. The bread with higher fat level (6%) remains softer than bread with 2% fat.

The numerous investigators have indicated that shortening soften bread by acting as a lubricant. However, this theory fails to explain that why fats are more effective than oils. Since hard and semihard fats would not blend with the gluten as completely as oils, it has been suggested that they remain immissible, which in turn weaken the cell structure, resulting in soft bread. The beneficial effect of lard may be due to the partial hydrolysis into monoglycerides during baking, which retards staling.

6. Effect of salt level

Although salt can influence the rate of staling, but from the practical stand point it is not a common practice to control staling by modifying salt level in bread formulation. The bread made without salt addition becomes firm than bread made with 2 to 3% salts.

7. Effect of yeast level

The yeast level influences the bread staling. The higher level of yeast in dough results in firmer bread.

8. Effect of egg addition

Both egg white and egg yolks are found to increase the bread volume and addition of yolk also results in a softer and more uniform crumb structure. Bread containing 2% egg white, stale to the same degree as bread with no egg, whereas the bread with 2% egg yolk do not stale as rapidly as the without egg. Certain component in egg yolk may be responsible in reducing the rate of starch retrogradation in bread during storage.

9. Influence of milk solids

The level of milk solids used in formulations can have a significant effect on initial crumb softness. The increased level of skim milk solids (0-8%) lowers the rate of staling in bread during storage.

10. Influence of modified starch

Higher level of damaged starch (25-30%), increases the baking absorption, which ultimately decreases the rate of staling of bread when made with and without malt by Chorleywood bread process and from high protein flour without malt using the sponge method.

11. Influence of various protein additions

The loss of moisture from gluten system is considered as the main reason for bread staling. It is more likely that hydrated proteins of the natural crumb undergo mild changes of first order reaction during baking and storage, which may be due to the denaturation of proteins leading to configuration changes and this result in the irreversible modifications in the water structure of gluten. Albumin is found to be most effective in retarding staling. The addition of soy flour at 1.5 % level has also been found to reduce both the rate and degree of staling.

12. Influence of enzyme addition

Low level of (3 to 6 SKB units) alpha-amylase isolated from *Bacillus subtilis* exerts beneficial softening effect in bread. The key to bacterial alpha-amylase functionality is its thermostability (stable even at 90°C) since its action does not take place until starch has gelatinized. Thus, it is concluded that the enzyme has a hydrolytic effect on starch, which results in the formation of low molecular weight fragments that, in turn, retard staling.

Lipoxygenase, an enzyme found in soyflour, not only results in a natural bleaching and oxidation of dough, but contributes towards the inhibition of crumb firming through an involvement with gluten development.

13. Influence of potato addition

Mashed potatoes with higher degree of polymerization and higher molecular weight of potato starch complexes with wheat starch account for slower staling rate. Higher the potato levels fresher the product.

14. Role of moisture in bread staling

The effect of water on starch in bread may vary according to the amount of water present in it. When amount of free water present is more, the swelling of granules of starch increases and a certain amount of soluble starch especially amylose leaches out from the granules to the surroundings. It affects the association of starch granules with protein matrix and leads to increased rate of staling.

Amylose of the starch granules holds the water by hydrogen bonding which interlinks the starch molecules together. It is well accepted that moisture content of bread influences the staling rate. Higher moisture content of bread also means higher yield. The safe limit of loaf moisture is 38%. Bread at this moisture content, will stay fresh longer than loaf moisture of only 35 to 36%.

15. Influence of storage temperature

Bread stored at -22°C remained acceptable even after 40days; however, the bread stored for longer period or at temperatures above -22^{0}C developed an off-odour. Refrigerated storage accelerates the rate of staling and after prolonged storage (after 5 days) both conditions (refrigerated and room conditions) produce the same degree of staling. The only advantage of refrigerated bread would be that, the bread stored at room temperature become moldy whereas that stored at refrigerated temperature did not have any mold growth after 7 days of storage. The faster rates of freezing and thawing retains softness in bread during storage.

At higher storage temperature (Hot or more) certain reactions occur rapidly causing off-flavours and gradual darkening of the crumb. Microbial spoilage also becomes more of a problem.

16. Effect of anti-staling agents

Over the years a number of anti-staling agents have been developed for use in bread making, out of which, the surfactants make a very important class of additives.

The surfactants act in two ways on the bread; as a softer and as a conditioner. Based on their mode of action, the surfactants can be classified as follows:

In general, the surface-active agents prevent staling of bread by complexing with the starch and gluten proteins. The surfactants especially those containing long carbon chain fatty acids are found to inhibit the gel formation of the starch by associating with the helical structure and preventing the swelling of starch granules to counteract staling. These have also been shown to develop hydrophilic and hydrophobic bonds between the starch and protein molecules and thus retard the staling of bread. From the above list, only the commonly used surfactants to counteract staling in bread will be discussed in the following pages.

(a) Sodium sieroyl-2-lactylate (SSL)

The SSL, a multifunctional conditioner, reacts with flour proteins and starch, and thus strengthens the 3-dimensional network of proteins, starch and lipids. This surfactant reduces the fat requirements by 33% and the resulting bread has greater softness and longer shelf life.

It is reported that the SSL alone at 0.5% level does not reduce the rate of staling of bread very much, but when it is added along with 3% shortenings, the rate of staling is reduced significantly.

(b) Mono-and diglycerides

Mono-and diglycerides inhibit the staling of bread either by attaching chemically with the starch and preventing the retrogradation or by mechanically covering starch granules and reducing their ability to absorb water. Monoesters of fully saturated long chain fatty acids (i.e. C-14 to C-15) form complexes with starch to a high degree and are relatively more functional in inhibiting bread staling. Higher the quality of monoglyceride, higher is the anti-staling effect. In the absence of monoglycerides water released by starch molecules during storage is immediately absorbed by gluten, leading to crumbliness of bread.

Polyoxyethylene monostearate (POEMS) when used as a surfactant at a level of 0.5 and 0.7% in bread reduces the firming rate of bread drastically without altering bread characteristics other than improving softness and tenderness. POEMS retards staling by precipitating amylose and probably, more importantly, have the ability to interact with starch granules through hydrogen bonding.

Polysorbate 60 (Polyoxyethylene sorbitan monostearate) acts as an anti-staling agent and dough conditioner in yeast-raised baked goods. This has been found to be more effective even at 0.2% level (on flour basis) and in combination with mono-and diglycerides, these also improve the physical and chemical characteristics of bread dough.

17. Influence of processing conditions

Proper processing helps in increasing the shelf life of the bread. Influence of processing conditions on bread staling is discussed as follows:

(a) Influence of dough mixing

The amount of mixing affects the rate of staling. Over mixing and under mixing affects the firmness of the bread significantly. The under mixing reduces the rate of firming and thus breads stays fresh for a longer time. Care should be taken against oven mixing. As a result of over mixing, dough tends to become too warm resulting in stickiness. During summer months, it is essential to use ice to control the dough temperature during mixing.

(b) Influence of fermentation time

Bread from over fermented dough gives a softer crumb than the one from under fermented. However, there is no difference in the firmness of bread from over fermented and optimally fermented dough.

Longer fermentation time during straight dough procedure produces bread with softer texture, even after a storage period of 3 days. The maintenance of vigorous and healthy fermentation and maturing of the dough brought about by the correct quantity of yeast and salt will definitely produce bread of good keeping quality.

c) Influence of proof time

Proofing time significantly (5% level) affects the firming of bread. The shorter proofing time give bread with slower firming rate. Over proofing of loaf produces bread of coarse grain and loss of moisture takes place more rapidly than the properly proofed loaf.

d) Influence of baking time

Both under baking and over baking affect the bread staling. Under baked loaf gives a very high oven spring and the effect is the same as that of over proofing. If the loaf stands too long in the oven for want of sufficient heat it actually dries out during baking. As the baking time is increased from 25 min (under baking) to 45 min (over baking), the bread firmness increases progressively. Proper cooling and wrapping of bread in moisture proof films is helpful in retarding staling of bread.

18. Freezing of bread

Bread rate of staling is reported to be more at refrigerated storage than at ambient temperature. Bread can be stored indefinitely without staling in the deep freezing conditions below –20ºC. The bread can be frozen by cold air blown over the product. Blast freezing is practiced to achieve fast freezing of bread so as to prevent staling during initial freezing.

4.4 SUMMARY

In commercial bakery units, the shelf life of bread is linked to their profitability and reputation in the market. Bread staling, development of rope and molds are the major problems of bread during storage. Such changes make the bread unfit for human consumption and bakers suffer in reputation and economically too.

Mold growth may occur at any place on the baked product while bacterial spoilage generally occurs in the icings, and fillings. Rope in bread is caused directly by bacteria known as *Bacillus measentericus*. The rope spores are present in the air and can also be carried by the particle of dust. This, including insanitary conditions in bakery, can infect the bakery raw materials and eventually cause ropiness in the bread.

Bread staling and development of rope and molds predominately affect shelf life and marketing of bread. Staling of bread is influenced by several factors such as composition of wheat mainly proteins, carbohydrates and pentosans, type and amount of shortenings, use of various protein additives, yeast, milk solids, enzymes, anti-staling agents, whole wheat flour, processing conditions, initial moisture and storage temperature of breads.

The effective method of preventing staling is the storage of bread at a temperature of -20°C (and below), but this is not economically and commercially feasible. So in practice, judicious use of a number of additives such as surfactants like SSL, CSL, EMG, DATA, etc., enzymes like alpha-amylase, lipoxygenase, shortenings and various other anti-staling additives can extent the shelf-life of bread reasonably and shall be adopted by our bakery industry. Development of wheat varieties with higher protein and pentosan levels can also help in improving the shelf life of bread. Use of whole wheat flour not only gives bread with better shelf-life but also better nutritional quality and yield of bread.

4.5 KEY WORDS

Rope: It is a disease which is caused by bacteria known as *Bacillus measentericus*. The rope spores are present in the air and can also be carried by the particle of dust. This, including insanitary conditions in bakery, can infect the bakery raw materials and eventually cause ropiness in the bread.

Bread staling: It refers to all those changes except microbial that occur in bread after baking. These undesirable changes affect flavour and taste of bread and hence bread become unacceptable to the consumer. Changes occur in both crumb and crust of the bread, however, crumb firmness is more correlated with bread staling.

The crust staling: Crust (outer covering) of fresh bread is crisp, brittle and somewhat dry. On staling it becomes soft, tough and leathery. This is caused due to migration of moisture from the moist center crumb to the crust.

Crumb staling: It is proposed that the change in starch fraction is the main reason of crumb (internal texture) staling. The starch cells absorb more water when bread is fresh and have alpha-pattern which on lowering of temperature, changes slowly to the beta pattern, which holds less water. As the crumb of bread stales it becomes drier, less elastic, crumbly and harsh textured.

Retrogradation: It is the reaggregation or recrystallization of starch fraction particularly amylase fraction after baking. It makes the bread tougher, harder and drier.

4.6 SELF ASSESSMENT QUESTIONS

1. Differentiate between microbial spoilage and staling of bread.

2. What do you understand ropiness in bread? What causes ropiness?

3. How to detect rope problem in bread?

4. List means to control ropiness in bread.

5. Which species of mold infect bread? How mold growth in bread can be controlled?

6. Classify staling of bread. What changes occur in stale bread?

7. What causes of bread to stale?

8. Discuss factors affecting rate of staling and different approaches to counteract staling.

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