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Dairy and Food Process and Products Technology

PROF. TRIDIB KUMAR GOSWAMI
AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT
IIT KHARAGPUR

Lecture 36

Potential technological significance of few enzymes in milk:-

PLASMIN:- Predominant indigenous proteinase in milk, optimally active at about 7.5 pH and about 37 ^{o}C. Plasmin and Plasminogen originate from the mammal's blood and are predominantly associated with the casein micelle in milk, used in cheese ripening and stability of casein micelles in UHT milk.

LIPOPROTEIN LIPASE:- optimal activity at pH 9.2 and 37 ^{o}C, relatively heat-labile enzyme. Initial digestion and absorption of milk lipids in the intestinal tract and flavour development in certain cheese from raw milk. Hydrolytic rancidity develops

Alkaline Phosphatase (ALP): - Optimum activity at pH 9.0 – 10.5 and about 37 ^{o}C, relatively heat – sensitive and its thermal stability is only slightly higher than that of non – spore forming pathogenic bacteria, indicator of Pasteurization efficiency.

Sulfhydryl oxidase:- catalyzes oxidation of thiols and formation of disulfide bonds in proteins and peptides. Sulfhydryl oxidase treated UHT milk may have longer flavour retention ability due to reduced lipid oxidation.

Lactoperoxidase:- relatively heat stable milk enzyme, requires 80 ^{o}C for thermal inactivation, anti bacterial agent, ph @ 8, exists primarily in milk serum

N-acetyl-p-D-glucosaminidase – activity diagnosed for mastitis test.

Catalase – associated with somatic cell membrane

Xanthane oxidase – contains all of the molybdenum in milk.

Superoxide dismutase – protective effect on lipid oxidation

γ- Glutamyltransferase – Transport of amino acids into mammary gland

γLactose synthase – synthesis of lactose

- Vitamins:-
  - **Vit A, Vit B_1,(thiamin) Vit B_2 or G (riboflavin),**
  - **nicotinic acid (niacin),**
  - **Vit B_6 (pyridoxin),**
  - **Pantothanic acid, Vit C (ascorbic acid),**
  - **Vit D, Vit E (alpha-tocopherol) and Vit K.**
- **Gases**:-
  - **Milk contains 7-10% by volume of gas**.
  - **CO_2 comes from udder,**
  - **N_2 and O_2 are taken during milking. On standing the amt. of gas becomes less.**

- Non-protein nitrogenous substances:-
  - urea, amins, creatinine, creatine, uric acid, adenine,
  - guanine – ranging from 1.5 to 10 parts per million.

- Milk
  - Water
  - Total solids (TS)
    - Fat (Lipid)
      - True Fat
        Several fatty glycerides
      - Associated substances
        - Phospholipids (lecithin)
        - Cholesterol
        - Carotene
        - Vitamins (A,D,E,K)
    - Solids-not-Fat (SNF)
      - Next Page

Solids-not-Fat (SNF)

- Lactose (milk sugar)
- Nitrogenous substances
  - Non protein (Urea, amins, creatinine, creatine, uric acid, adenine, guanine)
  - protein
    - Casein (α,β,γ)
    - Lactalbumin (α-Lactalbumin)
    - Lactoglobulin (β-Lactoglobulin)
    - Proteose peptone
- Mineral matter
  - Phosphates, citrates, chlorides of K, Na, Ca, Mg, Traces of Fe, Cu, I, etc.
- Other constituents
  - Pigments
  - Dissolved gases
  - Vitamins B-complex, C
  - Enzymes, Bacteria

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Lecture 37

Factors Influencing Growth of Microorganisms in Food

- Factors that influence microbial growth
    - In production and preservation
- **Conditions naturally present in food termed intrinsic factors**
- **Environmental conditions are termed extrinsic factors**
- **Factors combine to determine which microbes grow in particular food and at what rate**

- **Intrinsic factors**
  - **Multiplication of microbes is greatly influenced by inherent characteristics of food**
    - **Microbes multiply most rapidly in moist, nutritionally rich, pH neutral foods**
  - **Intrinsic factors include**
    - **Water availability**
    - **pH**
    - **Nutrients**
    - **Biological barriers**
    - **Antimicrobial chemicals**

– Water availability

- Foods vary dramatically in terms of water availability
  - Fresh meats and milk have high water content
    - » Supports microbial growth
  - Breads, nuts and dried foods have low water availability
    - » Selective microbes can grow in these specific environments
- Water activity (a_w) used to designate amount of water available in foods
  - Pure water has a_w of 1.0
    - » Most bacteria require a_w of above 0.9
    - » Most fungi require a_w of above 0.8
    - » Most molds require a_w of above 0.7

– **pH**

- **Should be determined to know which organisms can survive and thrive on which specific food**
- **Many microorganisms are inhibited by acid conditions**
  - **Exception is lactic acid bacteria**
- **Lactic acid bacteria used in fermentation process of food production**
- **Also prime cause of spoilage of unpasteurized milk and other foods**
- **Fungi able to survive at relatively low pH**
  - **Most acid foods spoil from fungal contamination as opposed to bacteria**
- **pH can determine bacteria's ability to produce toxin**
  - **Toxin production of many organisms is inhibited by acid pH**

- **Nutrients**
  - **Nutrients in food determine which organisms can grow in foods**
- **Biological barriers**
  - **Rinds, shells and other outer coverings help protect foods from microbial invasion**
    - **Microorganisms will eventually breakdown coverings and cause spoilage**
- Antimicrobial chemicals
  - **Some foods contain natural antimicrobial chemicals that inhibit growth of organisms responsible for spoilage**

- **Extrinsic factors**
  - **The condition of storage of food largely dictates the extent of microbial growth**
  - **Microbes multiply rapidly in warm, oxygen-rich, moist environments**
  - **Extrinsic factors include**
    - **Storage temperature**
    - **Atmosphere**

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Lecture 38

- **Extrinsic factors**
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    - **Storage temperature**
    - **Atmosphere**

- Storage temperature

- **Rate of microbial growth is controlled by storage temperature**
  - Availability of water below freezing is significantly decreased
    - » **Crystallization of water makes it unavailable halting microbial growth**
  - **Enzymatic action at low temperature (above freezing) is very slow or non-existent**
    - » Results in inability of microbes to grow

– **Atmosphere**

- **Presence or absence of <u>oxygen</u> affects type of microbial population**
  - **Obligate aerobes cannot grow under <u>anaerobic</u> conditions**
  - **Obligate anaerobes will grow in <u>anaerobic</u> conditions**
    - » Includes certain food borne pathogens

Milk & Milk products Spoilage

- Milk: Unique flavor and texture
- Rejected if off or other flavor is detected
- Spoilage occur by Biochemical reactions of contaminating bacteria (initiated after milking)

Manifestations of spoilage

1) Lactic acid production/ souring
2) Proteolysis
3) Lipolysis
4) Sweet curdling

Spoilage Process

- Fermentation-milk constituents by microbes
  - Normal fermentation: curdling
  - Abnormal fermentations: Gassiness, ropiness, proteolysis, sweet curdling, lipolysis
- Mixed fermentation: two or more fermentations occur simultaneously, e.g., acid and gas (coliforms)

Associative action

- Combined action (two or more-species or genera) or genera)
- Desirable or undesirable

- Changes not possible by single microbe
  - Three types
    - ✓ Synergism
    - ✓ Metabiosis
    - ✓ Antibiosis

Synergism

- Changes brought by two microbes (not single one)
- Mixed starter (Streptococcus lactis & Leuconostoc spp.)
- Leuconostocs convert citrate to volatile citrate to volatile compounds (only at low pH)
- Lowering of pH due to lactic acid production S. lactis

- **Blue discoloration**: Pseudomonas syncyanea only in association **with S. lactis**
- **Lactic acid bacteria required for 'yeasty creamy' defect (Candida pseudotropicalis, Torulopsis) in cream**
- **Coagulation of milk & foaming for subsequent gas production by yeasts**

<u>Metabiosis</u>

- **Food chain is formed**
- **Metabolic end products of one are utilized as food by other for producing final change**
- **Swiss cheese: lactose to lactic acid (bacteria), utilized by propionibacteria to produce propionic acid (flavour)**

- Spoilage of Raw milk at room temperature
- Curdling of milk by S. lactis (precipitation of casein) up to 1 % acidity
- Lactobacilli (L. casei) convert rest of lactose to lactic acid 2% lactic acid
- Molds (Geotrichum candidum) growth on surface and reduce acidity by oxidizing lactic acid to CO_2 and H_2O.
- Reduced acidity, proteolytic spore formers (Bacillus spp.) degrade casein fraction
- Sub-sequently lipolytic bacteria develop and utilize fat fraction
- Decomposed mass-water, inorganic substances, CO_2, NH_3, H_2 etc.

Antibiosis

- One organism inhibits/suppresses growth of the others
- Lactic acid -bacteria causes the inhibition of proteolytic organisms (spore formers)
- Starter cultures do not propagate well in reconstituted milk - certain preformed substances inhibitory to starter bacteria are elaborated in milk and get carried over to the product during subsequent drying

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Lecture 39

Natural souring/curdling

✓ Raw milk held at ambient conditions

✓ Immediate effect is souring followed by curdling (due to acidity - lactic acid) by bacteria already present in raw milk

✓ Fresh milk normal acidity (0.14 to 0.19%)

✓ Milk sours (0.20 to 0.25%)

✓ Milk curdles (0.50-0.65%)

✓ COB test positive (0.30 to 0.45%)

✓ Acidity increase even after coagulation of casein till lactic acid producing flora inhibited or till whole of lactose is exhausted (acid tolerant organisms predominate)

Acid coagulation

- Interaction of lactic acid with calcium bound to casein - precipitation of casein - curd (pH range 4.64 to 4.78)
- Lactic streptococci - S. lactis, S. cremoris (room temperature)
- Gets inhibited at 1%
- Lactobacilli - L. casei (at room temperature), L. acidophilus and L. bulgaricus (optimally at around 40°C)
- Gets inhibited beyond 2% level of lactic acid
- Leuconostocs - Leuco. Dextranicum and Leuco. Citrovorum - responsible for flavour development and lower level of lactic acid

Other streptococci

- S. Thermophilus at around 45 ºC though it is produced slowly even at lower tempera range. This organism is also capable of surviving higher heat treatments such as pasteurization.
- S. liquefaciens at about 31 ºC. Milk is rapidly coagulated followed by proteolysis (causes the curd to shrink from the walls of the walls of the container and separation of whey)
- Bacillus coagulalls - aerobic spore former - survive heating and multiply and produces lactic acid at 31 to 55 °C.

- Coliforms - E. coli and Enterobacter aerogenes Produces acid and gas (37 °C)
- The coagulum formed by lactic streptococci, S. themrophilus and lactobacilli is smooth and with typical clean sour flavour (used as starter culture for desirable fermentations)
- S. liquefacienls, B. coagulans and coliforms produce a coagulum with undesirable flavours due to liberation of certain volatile flavour substances from lactose, proteins and milk
-

Fluid Milk Processing

Raw milk storage

↓

Cleaning and decreaming (Separator)

↓

Homogenization

↓

Fat standardization

↓

Heat Treatment

↓

Chilling (Heat exchanger)

↓

Intermediate storage

↓

Filling/Packing

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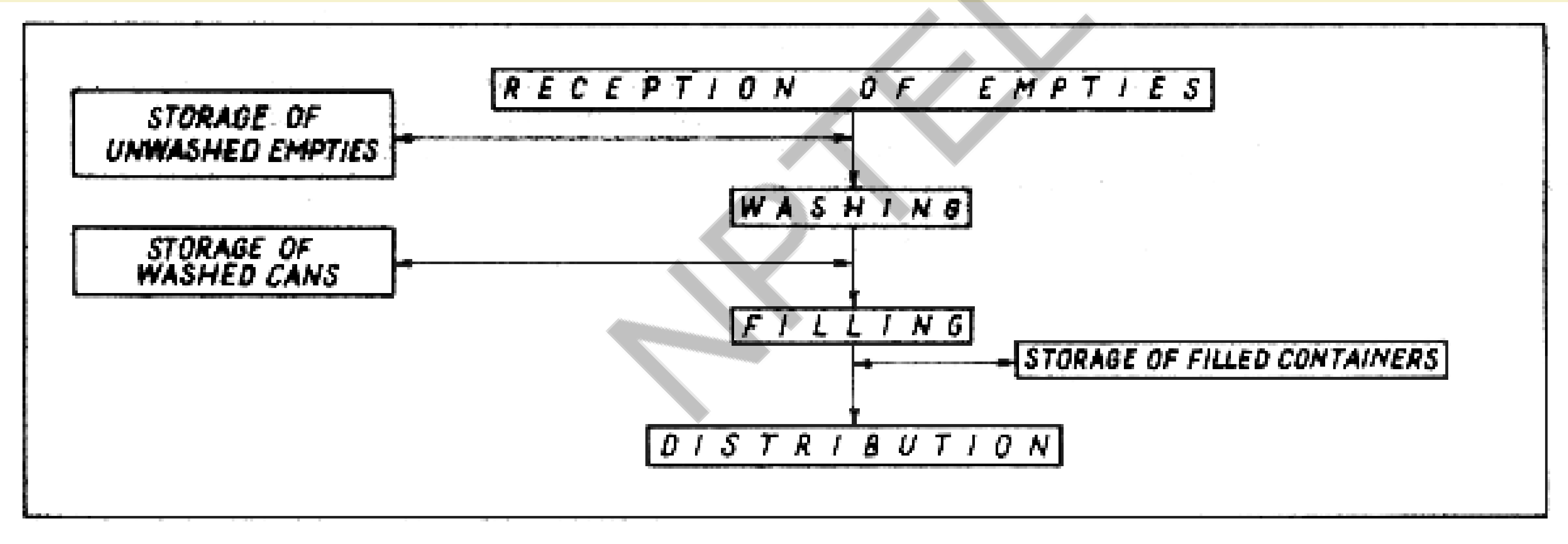
Lecture 40

PACKAGING SYSTEMS:-

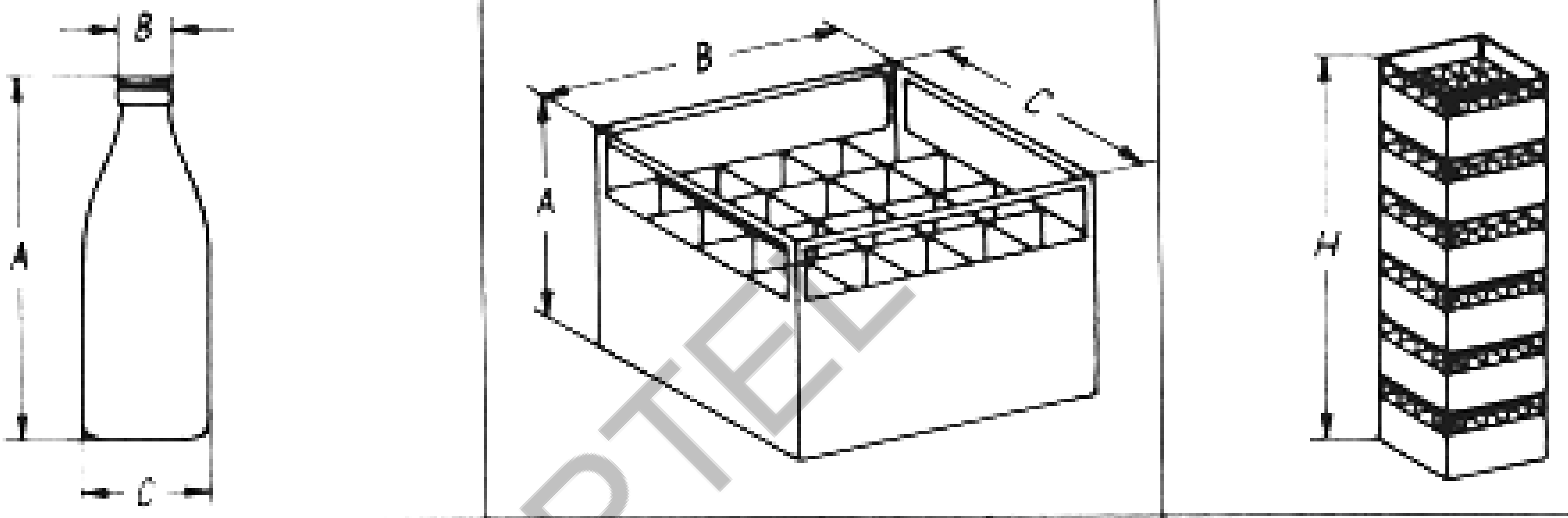
Returnable containers:- Concern using returnable containers are the collection of empties and washing prior to re-filling –- **necessity of intermediate storage facility.**



Sequence of operations with returnable containers

Bottle washing, filling and capping machines should be of matching capacity, otherwise the labour-intensive operations of decrating and crating, as well as unstacking and stacking, would have to be repeated unnecessarily.

Pasteurized milk in bottles. Bottles with wide necks (36 to 40 mm), suitable for sealing with aluminium foil caps made in - situ from reeled strip, form the most common system for packaging of pasteurized milk in returnable containers. The bottles are placed into crates, formerly made of galvanized steel wires or strips and nowadays usually of plastic. The crates have internal divisions so that the bottles are not in contact with one another to minimize risk of breakage. They are designed to interlock, so that a stable stack can be built.



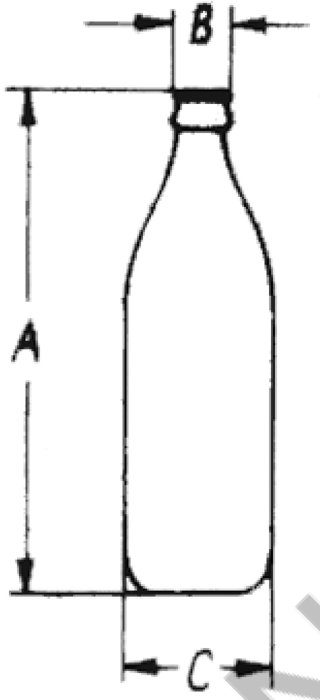
Volume	Bottle				Crate				Stack
	A	B	C	Weight	A	B	C	No.	H
	mm	mm	mm	g	mm	mm	mm		mm
0.5 l	200	36 – 40	73	418	270	430	350	20	6 – high 1545
1.0 l	267	35 – 40	89	610	330	505	320	15	5 – high 1590

Dimensions of glass bottles, crates and stacks for pasteurized milk

The floor area occupied by one stack of crates is thus about 0.15 m^2, equivalent to a milk storage capacity of 400–470 litres / m^2 depending on bottle capacity and stack height.

The initial high cost of a glass bottle prevents single-service use for pasteurized milk. The effective cost depends on the number of times the bottle can be re-used which in turn is determined primarily by the effectiveness of the bottle recovery system and the ability of the bottle to withstand breakage.

Sterilized milk in bottles. Bottles used for in-bottle milk sterilization have narrow necks (26 mm) so that a more effective seal can be made. Prefabricated crown seals are used to seal the bottles. These bottles must be able to withstand not only mechanical shocks during handling, but also thermal shocks during sterilization and, even more, during cooling. As the milk in the bottle is heated and expands during heating more than the bottle, the air above the milk becomes compressed and the pressure inside the bottle exceeds the external pressure. The contraction of the milk as it cools below the filling temperature results in a vacuum in the space above the milk. This vacuum may encourage contamination through the seal between the bottle and the cap. It is therefore important that the seals be fully airtight.

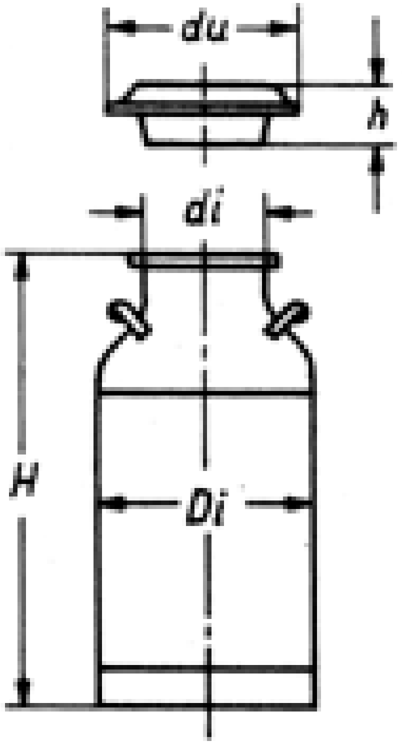


Volume	A	B	C	Weight
	mm	mm	mm	g
0.5 l	232	26	75	460
1.0 l	294	26	89	735

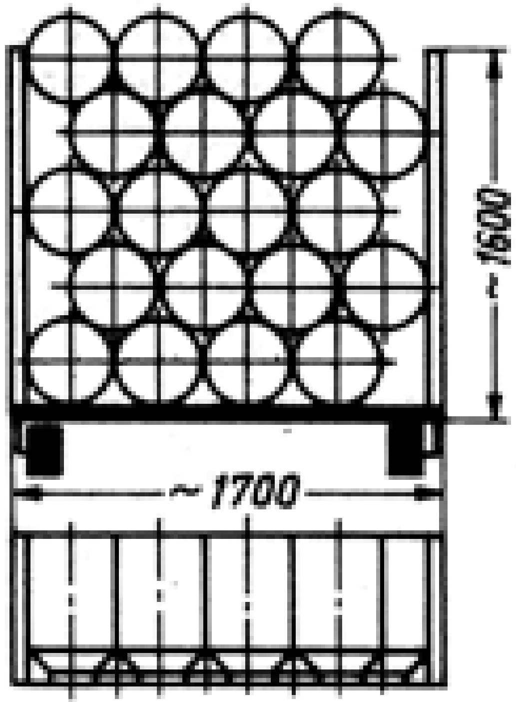
Dimensions and weight of glass bottles for sterilized milk

Pasteurized milk in cans. The aluminium milk can has proved very satisfactory in service and, since the beginning of the second half of last century, has rapidly replaced the previously-used tinned mild steel can. In recent years high density polyethylene cans began to be **introduced** in a number of countries, but have not proved popular for various reasons. The most common are cans with lids which do not require rubber gaskets, an adequate seal being achieved with sunken grip or mushroom lids. Because of mechanical washing problems lids attached to the cans by chains are no longer used. Through simple arrangements at the lid ring lead or other seals can be applied to make the contents of the can pilfer-proof.

The cans may be palletized, but more often floor conveyors are used. Full cans are stored in one layer, thus allowing about **320 to 360** litres of milk to be stored per square metre excluding access space. Empty cans, after washing, are stacked in layers horizontally, up to the height of **1.5. m**. For storing and moving washed empty cans simple trolleys on which the cans can be stored in 4–5 layers are very useful; for instance, about 20 cans each of 40 litres capacity can be stored on trolleys about **1 700 × 700 mm** with a supporting frame made of a 1/2" pipe.



	20 litres	30 litres	40 litres	50 litres
H mm	445	560	613	650
Di mm	285	295	330	360
di mm	180	200	200	200
du mm	215	235	235	235
h mm	65	65	65	65
Weight with lid in kilograms	5,7	7,0	7,3	10



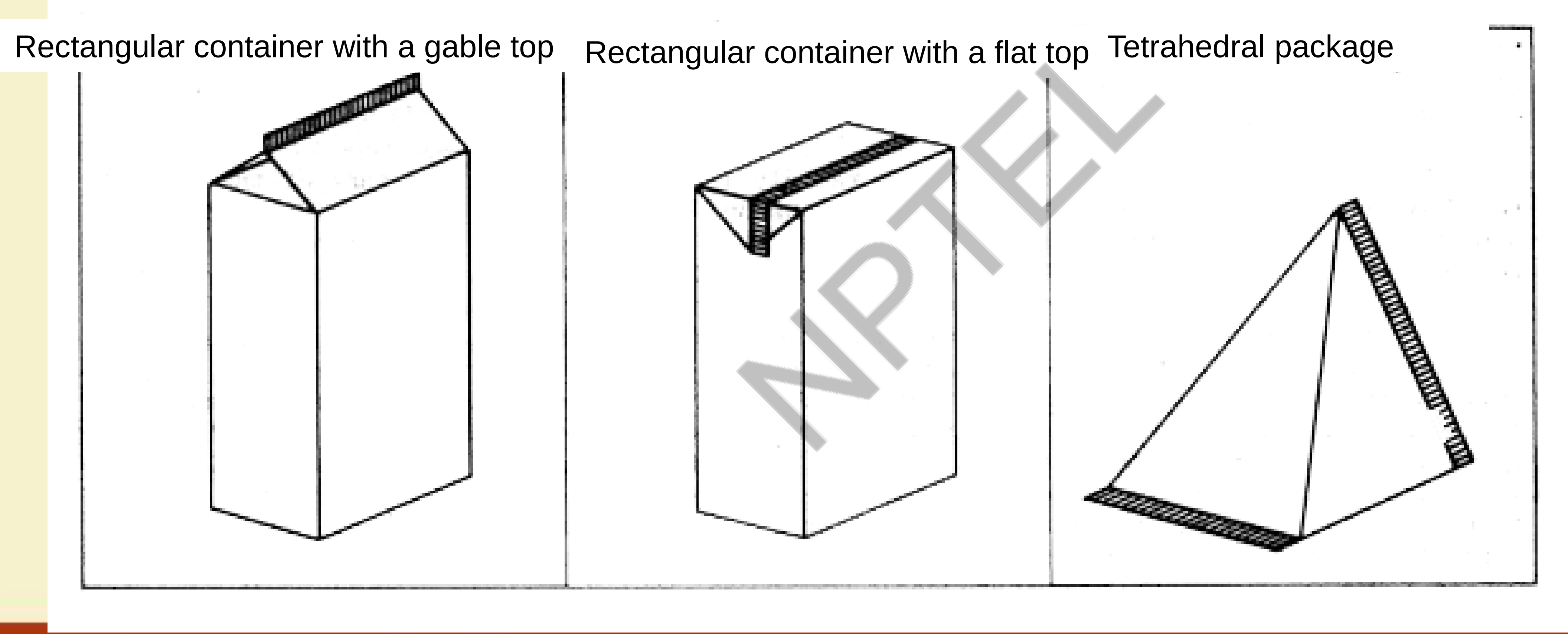
Empty can trolley

Dimensions, weights and stacking of empty pasteurized milk cans

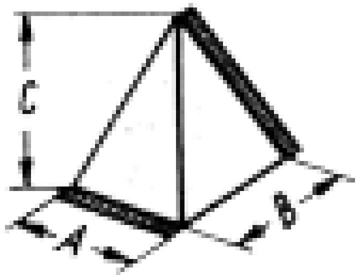
Single-service containers:-

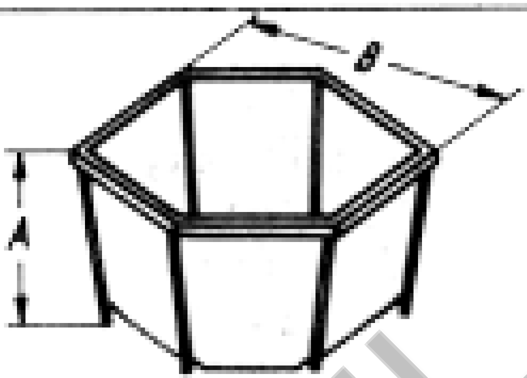
The common feature of single-service containers is that after emptying they are discarded. This fact has a significant impact on the milk plant construction, organization, and on the economics of the whole enterprise. There is no collection and washing of the milk packages - only crates are collected and washed, but even these may be **replaced** by single-service delivery wraps, trays or boxes. Palletization may be applied as in the case of returnable containers. Intermediate storage of packing material and filled packages **is required** and this must be provided in the plant.

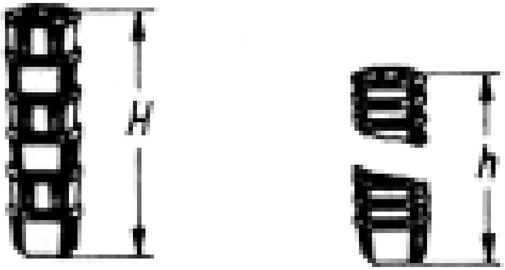
Two basic types of single-service containers are considered i.e., cartons and plastic sachets. Cartons are usually made in one of these shapes



Basic shapes for milk cartons





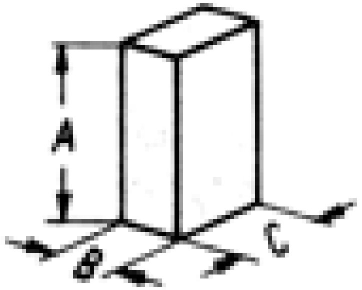
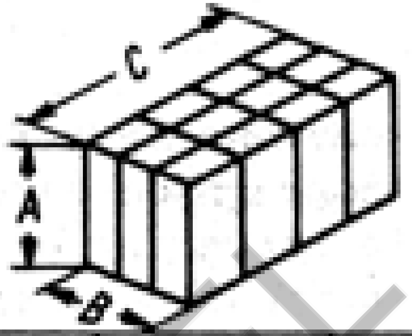
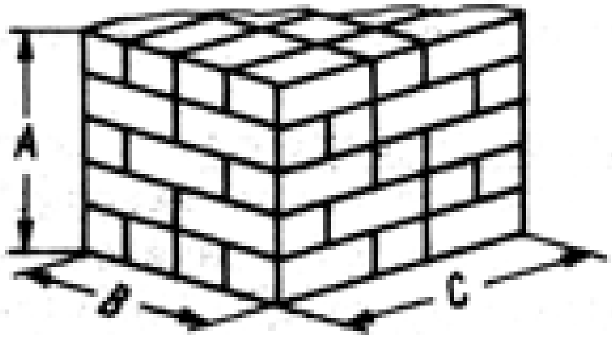


Volume	Package				Crate for 18 cartons			Stacking full (6)	empty (15)
	A	B	C	Weight g	A	B	Weight g	H	h
0.5 l	140	165	135	11.8	230	340	850	1230	1485
1.0 l	176	205	170	19.5	280	440	1600	1530	1630

Dimensions (in mm) of cartons, crates and stacks for pasteurized milk

UHT milk in cartons:- Rectangular cartons made from polyethylene **laminated** paper board in shrink-on wraps **strengthened** by corrugated cardboard trays **forms** a system for aseptic packaging of UHT treated milk.

The cartons are produced continuously from a roll of plastic-coated paper which is chemically and thermally sterilized before being shaped and sealed into a tube. The tube is **filled** continuously with UHT processed milk, after which the cartons are sealed below fluid level and formed into a rectangular shape. The **cartons** are filled completely and can be stacked.

Volume	Package				Wrapping			Stacking		
										
	A	B	C	Weight g	A	B	C	A	B	C
0,5 l	88	63	95	17,2	88	190	380	~880	~760	~950
1,0 l	167	63	95	25,2	167	190	380	~835	~760	~950

Dimensions (in mm) of cartons, packs and stacks for UHT milk

Thank You!!