Production Lines in Food Industry

Pavel Hoffman; the 10th semester (summer)

Practice requirements for process engineers

- Logical thinking
- Creative work and problem solution
- Knowledge of solved and related problems
- Exploitation of own knowledge and the others one
- Proceed from common to detailed (black boxes, balance of an all system or line and than subsystems and apparatuses)
- In process of a trouble shooting or optimisation of a line it is necessary to mind or take into account details and trifles.
- It is important to interest in a user of your designs and proposals
- Do not hold up on one solution or proposal, but revise it according of new pieces of knowledge or situation development.
- To have in reserve several alternative solutions or variants for a case that there are problems with an original ones.
- A bad operation (troubles) of an apparatus, line etc. usually has more causes, not only one.
- It is necessary to check given data, measured up data, yours own results etc.– incl. theirs objectivity (principles of energy and mass conservation too).
- It is necessary to calculate with an uncertainty and inaccuracy of given data in yours proposals.

- In your proposals calculate with an irresponsible human factor (copperhead) and/or unexpected troubles or process problems (in a solved line or in an others one) → fool-proof machinery.
- Take into account difference between theory and practice (k values for evaporators, power requirement for stirrers).
- Approach to solution has to be global (acquisition costs, running costs, work difficulty, maintaining time consumption, service and spare parts availability, benefits and savings, ecology, future aspects (output, legislative etc.) ...).
- It is useful to design a line reconstruction in several steps (1^{st} step = a worse line problems correction; low money, high effect; 2^{nd} step = optimisation of a line; 3^{rd} step = a correction of failings or problems of 1^{st} and 2^{nd} steps; final optimisation).

Philosophy of production lines design

sheets 10-12

Basic terms

- Production line = serviceable and efficient group of production equipment (apparatuses or machines) in which is a technological process realised. The system is characterised by a flow of mass, energy and information.
- Technological process (TP) = organised sequence of physical, chemical, biochemical changes of substances of purpose to make a product (semi-product etc.) of required quality. TP is divided to operations (steps).
- Technology of production = process of technology (technology) describing a process how is a final product made from a raw materials and/or semi-products.
- Operation = the smallest part of a process from a point of view of its time and space layout. Operation is usually a complex of several physical or chemical etc. processes (distillation, evaporation and drying = heat and mass transfer and flow; packaging = mechanical operation.).
- Machinery = machines and apparatuses in which is realised a technological process.
  - *Working machines* – mostly mechanical action to material (product)
  - *Apparatuses* – a special space with defined physical, chemical etc. process conditions
- Know-how = a complex of all knowledge of a technology including its acquirement (job training).

- Production line output = is given in pieces/s, pieces/h – wrapping machines; kg/s; t/d – sugar factories; l/d – dairy industry; hl/year – brewery ....
- VL = PL = production line = a system compound of sub systems and elements
- System = organised group of elements that are combined each other and serve for given duties. It is a set of objects and functions and has these basic characteristics:
  - *System content* = material (machines, apparatuses) necessary for its function (incl. staff and treating material)
  - *System structure* = space and organising arrangement (vertical, horizontal, serial, parallel ..)
  - *Communication* = equipment for transport of material, energy and information among single elements of a system (line) – - piping, conveyers, staff, cabling ...
  - *Control* = insure a proper process of a technology from a point of view of quality, output, time path and sequence with other elements or processes in a line. A staff or controlling apparatuses of various level or a mutual combination control a PL.

Reserves in PL (sheet 12)

- Technological reserves – are necessary for a technological process (cakes of cheese or pieces of meat in ripening cellars or boxes, beer or vine in fermentation tanks)

- Continuous reserves – are necessary from organisation reasons for a maximal utilisation of all line elements
  - *Balancing reserves* – equalises output and input variations among machines and apparatuses in line, between continuously and periodically working apparatuses etc.
  - *Transport reserves* – material in piping, on conveyers ....

- Safety reserves – are necessary for a good line working in a case of some troubles of an element (time for a reparation etc.)

Example: (sheet 13)
Technological processes and machinery in meat industry

Process	**Realisation**
Technology of meat processing	Butchery factory
- cutting - fresh meat - smoked meat products - boiled meat products	- cutting room - packing - smoked meat manufactory - boiled meat manufactory
Technology of smoked meat production	Line of smoked meat
- salami - bratwurst - frankfurters	- salami line - bratwurst line - frankfurters line
Technology of frankfurters production	Line of frankfurters
- weighing → disintegration → mixing → filling in covering → smoking → boiling → cooling	scale → cutter → mixer → filling machine → smoking -chamber → boiling – chamber → cooling-chamber
Physical process of boiling:	Process and strength calculations, setting of process parameters
- unsteady heat and mass transfer	
Biological process of boiling:	
- micro-organisms growth and activity stopping	

<u>Production lines subdivision</u> (sheet 14)

<u>According material movement</u>

- *periodically working* - < outputs, for special batch processes
- *continuously working* - > utilisation of capacity, needs of > reliability + control

- **<u>According product character</u>**

  - *serial* – piece-goods,
  - *mass* – liquid or loose materials (grain, flour, ...)
  - *infinitive* – foil on a roll, extruded material ....

- **<u>According machinery</u>**

  - *set of machines* – mechanical operations (packing, manipulation ....mixing)
  - *set of apparatuses* – mostly chemical, physical and biochemical processes (heating, cooling, boiling, biotechnology, ... mixing)
  - *set of staff and tools* – craft work with or without mechanical instruments
  - *combination*

- **<u>According way of service and control</u>**
  - *manual controlled*
  - *mechanically controlled* – a control device is set to keep a parameter
  - *automatically controlled* – partially, fully, computerised

PL automation reduces a physical effort but increases psychical stress; computerisation highlights staff only for a critical situation.

Principles of production lines design (sheet 15)

- Product production in required quality and quantity with minimal costs
- Mass wastes utilisation as a raw material in the same or other line
- Waste energy utilisation in the same or other line
- Minimal pollution to living environment

Particularities of production lines in food industry

- ***Food chain*** = farmer → food industry → storage → distribution → consumer (→ = transport + event. cooling), every change of one link can affect the others

- ***Quantity of various products and technologies***

- ***Biological character of raw materials, semi-products and products*** → limited durability, instability, various properties that change with time or locality, demands for hygiene and sanitation

- ***Individual consumer behaviour*** – tastes vary, products are in or out, effect of financial situations and health conditions of people ..... → it is difficult to forecast it

Production lines building

= drawing up of a complete project and line building incl. auxiliary plants.

A project sets main mass, energy and information parameters of a line, space layout, specifying of equipment, transport ways, control etc. and consequently its economy. A complex approach to PL design and building is important.

Production line design steps – submitter, user

sheet 16

- branch prognosis ↕ marketing study (for what type of product
- long-range goals — will be interest, in what price
- product price relations — and quantity ....)
- new product development in a laboratory - technologist
- checking on of the new product quality - technologist
- technology proposal - technologist + engineer (feasibility)
- checking on of the technology on a pilot plant – technologist + engineer (plant design, participation on tests)
- marketing study – consumers interest correction and specification (quality, price and quantity of a specific product)
- investment intention = data for a designers (technologist, engineer, experts for automatic system of control, energy and energy saving)

It contains: output, line parameters, product quality, max. price of line and product, available raw materials and energy, manpower, location and space, know-how, terms, service life, ecological and legislative restriction, geologic conditions ......

Proposed technology process has to be optimal from a point of view of inlets and outlets and its control has to be easy → a continual process demands a reliable measuring of parameters of process, inlets and outlets etc. and reliable control components.

Production line design steps – designer sheet 17

(technologist, engineer, experts for automatic system of control, energy and energy saving, building engineer)

Design procedure:

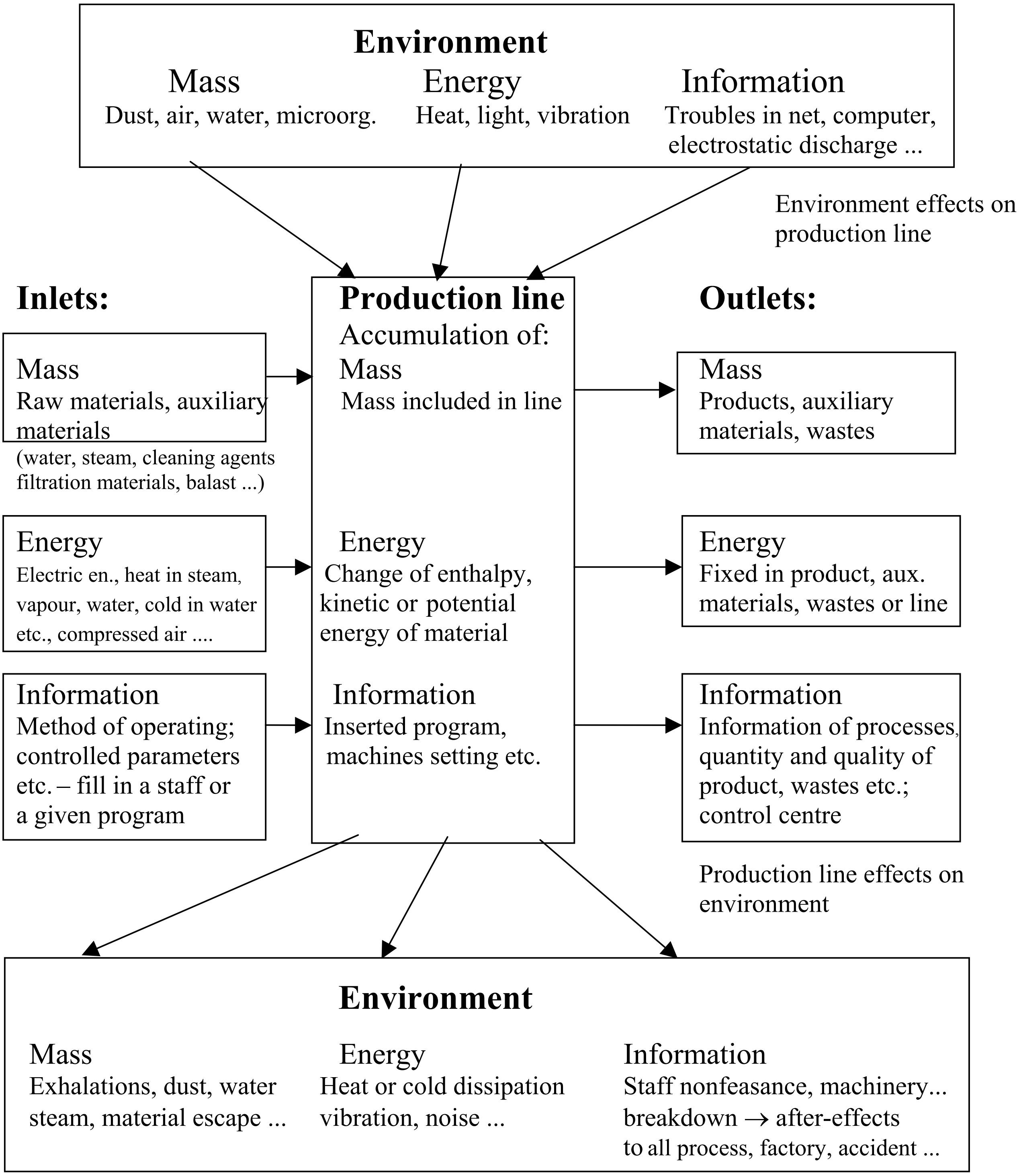
1. Background research
2. Results application to the specific conditions of solved problem
3. Comparison with the submission – critical submission checking
4. Critical checking of conventional processes and technology
5. Possibilities of improvement (energy, raw material, quality, savings, environment, control, work safety ....)
6. Selection of an optimal version – relationship to other lines in a factory, flow sheet
7. Reservation of machinery – purchase, development and design, modification ....
8. Economical evaluation – product and line price, investment return .....
9. Processing of design documentation on various levels

Manufacturer:

Prototype design, production, trial operation, tuning, documentation modification for a serial production.

Production lines supply is preferable to supply single machines or apparatuses $\rightarrow$ a know-how is sold x guarantee for all line

Balance sheet of a production line (technology process)



From most of line balances sheet follows that in products in principle is not energy → practically all inlets energy is dissipated to environment directly in heat losses or indirectly in wastes (cooling water, cooling towers, stack gases etc.).

Levels of production lines control sheet 20

- Manual control
- 1 controller (control device) controls 1 parameter to a set value
- 1 controller controls 1 parameter depending on other parameter (steam flow x temperature in an apparatus, inlet milk flow x outlet milk concentration ...)
- Mutual combination or possibly 1 controller monitors and controls more parameters
- Computer optimises work of all line (monitors and evaluates all important parameters of the line, gives off signals for actions for action parts (valves, butterfly valves, electric motors ....)

<u>It is necessary to count with an unreliable human factor and failure rate of a machinery</u>. A ways of it are:

- Minimise service, maintaining and adjusting requirements (wrong service, inadequate maintaining, bad adjusting → breakdowns)
- Plan of maintaining – utilisation of theory of reliability
- Diagnose a situation before a breakdown (temperatures, pressures, vibrations, leakage ....) → well-timed reparation in a proper time saves big losses

Line design steps

feed back

1. ***Complex line (technological process) design*** → balance, process linking, machinery and its parameters design, local optimisation
2. ***Optimal synthesis of line designs*** – effect of externalities (ecology, restrictions ...), optimisation of the whole line
3. ***Line design modifications*** – suggestions for the whole line optimisation and external conditions fulfilment
4. ***Final synthesis of modified line (technological process)*** – definitive optimal design of line fulfilling all conditions

An example of an evaporator control sheet 21

Course of energy consumption in a dairy and a sugar factory sheets 29,30

Branches of food industry in CR sheet 2

- Meat industry
- Dairy industry
- Mill and bakery industry
- Sugar industry
- Malt and brewing industry
- Vine and spirits production
- Fat industry
- Poultry industry
- Canning factory and ethanol production
- Starch industry
- Cooling and freezing plants
- Chocolate, sweets etc. production
- Tobacco industry

In CR food industry produced circa 14 – 15 % of all industrial production.

Food chain sheet 3

agriculture → transport → food industry → transport and distribution → consumer

cooling cooling cooling cooling

Family budget and foods

USA, Canada .... c. 15 %, EU .... c.15 – 25 %, ČR .... c. 50 % → 40 → 30 %, developing country till 95 %

Food losses x wastes

Developing countries till 80 % (hot weather, lack of technology),
Developed countries c. 20 %

Losses in the food chain:

Agriculture c.16 (22) %, food industry c.14 (8) %, distribution c. 4 %, consumers c. 66 %

- wasteless technologies → wastes are raw materials in other plant or other part of a line
- long-life products, good package
- manipulation, storage, transport etc. with regard to food material

Optimisation of food chain = optimisation of :

- product
- process
- raw material properties

Sugar: yield in t/ha of sugar beet x t/ha of refined sugar production
(amount of beets x sugar content in beets + composition (non-sugars)
→ refined sugar yield from sugar bougtht in sugar beets)

Corn: starch x gluten content (ditto wheat)

Potatoes: for starch production x for boiling or potato salad x chips production

Durability of foods, post-harvest life

- **good durable** – sugar, corn, flower, beans (soya, pea, bean ...)
- **medium durable** – potatoes, root crop (carrot, parsley ....), apples, hard cheeses, eggs ...
- **with artificially prolonged durability** – dried products, canned food
- **perishable** – milk, meat, fishes, vegetable, soft fruits ....

Food durability is affected by:

- food composition and water content
- way of storage (° C, % r.h., O_2, light, contamination ....)
- manipulation
- previous processing

Food composition

sheet 4

• **C, O_2, H_2, N_2** - proteins	building material		
- carbohydrates	energy		macro-nutrients
- fats	energy		
- water			
- minerals (ash)	Ca, P, Fe, S, Na, K, Zn ...		micro-nutrients
- vitamins	biochemical reactions		

- **water content** → food durability, weight

- **water activity** $a_W = p_{Pfood} / p_{Pwater}$ [0 – 1]

bacteria size c. 0,3 – 10 μm; needs $a_W > 0,90$

yeast size c. X0 μm; needs $a_W > 0,80$

fungi size c. X00μm; needs $a_W > 0,75$

are accustomed to an osmotic pressure 550 kPa (0,9 % solution of NaCl)

- Substitution of expensive animal proteins (meat) not only with cheaper vegetable ones (soya, egg white) but with starch or separate from bones too

- Producer tests composition of raw material and products → quality, price

Hydrocarbons = starches, sugars, fibres (cellulose, lignin)

Causes of food losses sheet 5

1. Effect of micro-organisms

- **Bacteria** – unicellular micro-organism (X μm; a_W > 0,90), vegetative and non-vegetative form (spores); < 100 °C (< 140 °C)

- **Yeast** - kind of fungus (X0 μm; a_W > 0,80), ≤ 60 °C; need sugars, N_2, a little O_2;

  quick propagation, good adaptation, sensitivity to an osmotic pressure (< 550 kPa)

- **Fungi** – mycelium and sporocarp (X00 μm; a_W > 0,75), ≤ 100 °C; pH = 3 – 6; needs moisture, air, a little nutrients x dangerous mycotoxins

- **Mould infection** – food fibrillation with a fungi mycelium → toxins production x sterilisation, << moisture, access of air prevention

- **Fermentative processes – bacteria, yeast**

- **fermentation** = decomposition of non-nitrogen matter (starch, sugar ..) when CO_2 is produced (production of beer, vine, vinegar, proofing dough ...); taste and smell changes, but acidity not

- **souring** = decomposition of organic matter, acidity goes up, gases are not in practice produced; milk souring = sour milk products, sauerkraut, sour cucumbers ...

x sterilisation(> °C), refrigerators, freezers (< °C), access of air prevention, concentration increase (< a_W) → worse conditions for micro-organisms

- **Decay** – nitrogenous matter decomposition = proteins

  - bad smell, NH_3, CO_2, H_2S are produced
  - 1st step – alkaloids are produced but smell and taste are good
    → very dangerous (botulism = sausage (cane) poisoning)
  - 2nd step – total decay – disgusting but relatively harmless products

2. Effect of enzymes

sheet 6

- Enzymes are catalysts of chemical reactions (favourable → biotechnology) that decays food; a very small amount of enzymes is sufficient
- Enzymes are:
  - hydrolytic – starch hydrolyse to simple sugars
  - oxidising
  - reducing
  - fermentative
- Enzymes (ferments) activity depends on a temperature (graph – maximum is between 20 – 60 °C)

3. Effect of chemical reactions

- These reactions are inhibited by enzymes inactivation – oxidation, hydrolysis, reduction, other reactions

4. Effect of radiation

- Light, UV radiation, electromagnetic radiation,

5. Mechanical effects

- peel, shell, skin = natural cover of food
- inconsiderate manipulation → surface layers damage, surface layers structure disturbing → decay processes
  (x do not wash eggs before a storage → wash-up an natural antibacterial egg protection → lower durability)

6. Uncontrollable decrease of water content

- Desiccation of fruits and vegetables x controlled dehydration (drying)
  Prevention = controlled atmosphere during fruits or vegetable storage
  (→ temperature, humidity, content of O_2, CO_2, ethylene ....)

<u>Means for food durability prolongation</u> sheet 7

- **<u>Cleanness</u>** - *<u>physical</u>* – mechanical impurities
  - *<u>chemical</u>* – washing water, detergents, disinfectants ...
  - *<u>bacteriological</u>* – micro-organisms

- **<u>Chemical preservation</u>** – adding of bactericidal medium natural (sugar, salt, CO_2, ethanol, ethyl ...) or chemical man-made (formic acid, benzoic acid ..) x ? health hazard

- **Preservation with controlled dehydration** – water content decrease →
  micro-organisms activity stopping
  - *Dehydration processes* = filtration, membrane processes, evaporation, drying, freeze-drying (sublimation)
  - *Salt or sugar adding* – osmotic pressure changes to a value unfavourable for micro-organisms

- **Preservation by physical methods**

  - High temperature – pasteurisation
    - sterilisation
  - Low temperature – cooling (+ 5 to - 0,5 °C)
    - freezing (- 10 to - 30 °C)

Goals of food industry sheet 9

- To produce an eatable food from mostly uneatable raw material (corn, sugar beet, oily seeds etc.)
- To produce food with better quality, taste, digestible, longer durability etc.
- To conserve agriculture surpluses from harvest for year-long consummation

3 parts of food industry

- **Primary** corn → flour = agricultural product → semi-factured product (maybe eatable or uneatable) (semiproduct, half-finished product)

- **Secondary** flour → bread = semi-factured product → product
- **Tertiary** milk → dried milk

  meat → corned beef

  = agricultural product or semi-factured product

  → product with special properties (longer durability, instant, ready to eat ….)

Foods have to be:

- ***Healthy, ecological, natural*** = have to fulfil criteria of correct diet
- ***Correct*** – vegetable, fruits, milk, cereals …. are theoretically correct but from some locality they may be not healthy (contain Pb, Cd, Hg, PCB …)
- ***For a special purpose, goal-directed*** = their content and properties are modified for a special people group (children, sportsmen, convalescentes, special diets …)

Goals: Healthy foods have to be delicious and good-looking too.

Productions lines of a dairy industry

sheet 31

Milk products:

- market milk (standardised milk) – fat content 1,5 to 2,0 % (semi-fat), 3,6 % (full cream, unskimmed, whole milk)
- skimmed milk – fat content ≈ 0 % (fodder for hogs or calves, diet …)
- concentrated milk – sweetened or unsweetened ("condensed milk")
- dried milk – for drinks preparation, bakery industry, fodder ….
- cream with various fatness
- cultured-milk products – yoghurts, kefir, cream, buttermilk …
- curds (cottage cheeses), cheeses

- butter
- ice-creams
- whey (concentrated or dried) – for animal fodder, food fortification ….
- lactose (milk sugar - dried) – food fortification, diets ….
- casein (milk protein - dried) - food fortification, diets ….
- additives to bakery products, smoked-meat products, shortenings ….

Dairy location

Near a source of raw material (milk production, grasslands, cow-houses …) or near a products consumption (big cities).

Dairy types:

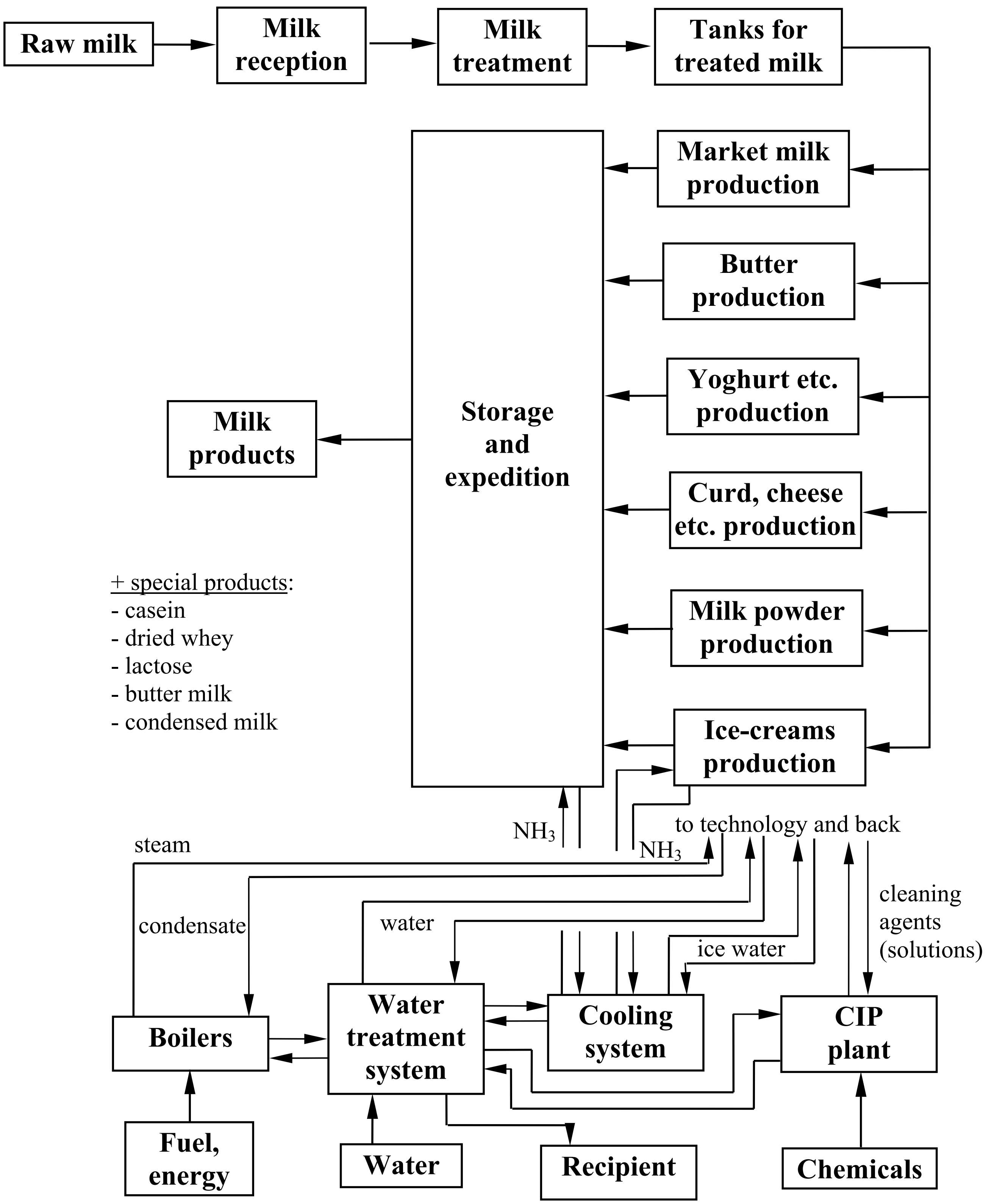
- Market dairy (chief products = market milk, cultured-milk, event. ice-creams…)
- Drying plant (chief products = dried milk, whey etc.)
- Cheese making (chief products = curds and cheeses)
- Butter factory (chief products = butter)
- Universal dairy (produces miscellaneous products)

- All the types of dairies product market milk for people round the dairy too.

Milk content:

- water – 84 to 89 %
- dry matter - 11 to 16 %
  - lactose 5,6 – 9,6 %
  - fat 2,7 – 5,0 %
  - casein 2,0 – 3,2 %
  - minerals 0,6 – 0,9 %
  - albumin, globulin 0,4 – 0,8 %
  - other organic matter 0,1 – 0,3 %

Dairy flow sheet



<u>Fresh milk quality</u>   sheet 35

- Fresh milk contains c. 200 – 2 000 000 micro-organisms / ml
- Bactericidal phase – c. 1 – 3 h after milking (milk drawing)

  In the time micro-organisms do not breed → in the time it is necessary to filter and cool down milk c. to 5 °C → cooled milk collections near farmers

- ***<u>Milk acidity</u>*** - 5,8 – 7,0 °SH - good quality
  - \> 8 °SH – on heat transfer area milk begins to agglomerate (forms deposits)
  - \> 10 °SH – pasteurisation is not possible
  - \> 12 °SH – milk agglomerates during boiling in an open cooker
  - \> 20 °SH – cool milk agglomerates in an open dish

- ***<u>Milk fatness</u>*** - → butter → price

- ***<u>Micro-organisms content</u>*** - → milk quality after pasteurization

  (E.g. for pasteurisation effect 99,99 % (rest after past. is 0,01 % of initial micro-organisms content)

  for 10^6/ml microorg. before pasteurisation → 100/ml microorg. after pasteur.

  for 10^3/ml microorg. before pasteurisation → 0,1/ml microorg. after pasteur.

Note: ° SH = ° Soxhlet - Henkel

= number of ml of 0,25 normal NaOH solution needed for neutralisation of 100 ml milk mixed with some droplets of phenolphtalein

Process of buttermaking

sheet 38

phosphatide layer

fat droplet - X0 µm

fat jut

butter grain

Fat in milk is in a form of small droplets. The fat droplets can contact together (agglomerate) only on places where are juts without phosphatide layer and on interface fat - air. The process of the fat droplets agglomeration is better when is higher fat concentration (fat droplets amount, droplets are more close), when fat droplets stroke each other and when is an optimal temperature. The agglomerates form butter grains.

From whence it follows a churns and buttermakers construction:

- hand churns
- drum churns (barrel, cylinder, double-cone) with movable and immovable built-in baffles
- continuous buttermaker

Churning time in a drum churn is c. 35 – 45 min for revolutions 20 – 45 1/min.

Churning temperature:

- sweet cream 9 – 14 °C; in winter >, in summer < (effect of milk composition owing to fodder kind; ripening time c. 2 – 4 h, cheaper production
- soured cream 9,5 – 15 °C; ripening time till 24 h, better butter quality

<u>Effect of a churning time</u>

- <u>too short time</u> → butter grains are < , in butter is > water, in buttermilk is fat (→ fat losses, bad butter quality)
- <u>too long time</u> → buttermilk and air are churned in butter → butter is viscous (pasty) with low durability (bad butter quality)

<u>The butter after the churning is raw</u> (= grainy, incoherent)

→ it has to be washed and kneaded

→ excessive free water has to be separated and butter grains coalesced (join).

The same is a principle of a continuous buttermaking.

Barley steeping

sheet 44

- amount of steeping water is c. ≈ 40 % of barley mass
- steeping time is 3 – 4 days
- for 1 t of barley it is necessary c. 2,2 m^3 of steep tank volume
- barley grains have to respire → aerating, water drainage, barley passing from one tank to an other one – 1/3 starting steeping, 1/3 aerating, 1/3 final steeping
- during steeping enzymes activate, dyes (pigments), tanstuffs leached out (partially sugars and minerals too) – c. 1 %
- steeped grain has not to sting (prick), has to be able to hook over a nail, inside is white and on a board writes

Barley sprouting

Goal: Formation of enzymes necessary for a starch saccharification

Sprouting ends when grains are cracked (with small root and leaf). Cellulose from cell-walls is hydrolysed.

Steps of barley sprouting – c. 7 days:

- wet barley – from steeping
- wet pile
- dry pile – after c. 48 hours
- dissilient (dehiscent) grains – a white point on a one grain end (= << root)
- young grain – small sprout (= root)
- green brewer's malt – a root is long like a grain, a leaf germ like 2/3 – ¾ of a grain

Two-floor malt kiln sheet 46

1. filing tubes
2. belt conveyor for green malt
3. regulating flap valve
4. mobile malt tedder
5. upper folding tray (floor)
6. lower folding tray
7. reservoirs for malt, conveyors
8. fan
9. air heater

<u>Malt kilning = malt drying</u>

Enzymatic processes needed for taste, good smell and beer quality are finished and in a proper time are stopped. For dark beers malt is dried with > °C (for Bavarian beer is air inlet temperature c. 100 – 105 °C → malt partially caramelises).

<u>Malt quality:</u>

- Well dried malt has to float on water level, bad dried settles down
- Moisture is c. 4 %
- Grains have to be brittle and white, full
- Bad dried grain after heating forms gelatinous structure and after drying hardens → does not soak

Fermentation cellar sheet 51

Fermentation stages:
- dusting – like white powder on wort level
- white rings on wort level
- high brown rings (foam)
- squirming rings
- brown cover (brown foam on level)

Fermentation time is c. so long in days as is beer percentage (sooner, now is shorter – Staropramen 10 % c. 7 days, 12 % c. 10 days)

Cylindric-conical tank

CCT substitutes fermentation cellar + storage cellar

Stages:
- wort filling event. in pre-fermenting CC tank
- inoculation; at 7 – 14 °C = brewer's yeast adding
- quick cooling to c. 0,5 °C
- settled yeast withdraval
- final fermentation

Total fermentation time is c. 2 – 3 weeks

Advantages: > performance, < built-up place, no cellars, easy CO_2 recovery

Yeast dosing in wort

sheet 52

The system is used in Braník brewery – yeast is automatically dosed in wort flowing to CC tanks. The dosage is controlled by a mixture colour.

- In England is used so call "top fermentation" at 20 – 25 °C → quick fermentation but in beer (wort) are foreign microbiological cultures → special taste for us (yeast flows ("settles") up to beer level)
- In Europe are cultivated yeast cultures for low temperature at c. 5 °C → no foreign cultures → no the tastes
  (yeast settles down to a vessel bottom)
- It is possible to use yeast ≤ 4 times → else is higher number of dead cells → autolysis → < quality
- Rest yeast is used as a fodder or for a special production (drying – tablets Pangamin)

Storage cellar

The secondary fermentation takes place in storage tanks – 2 steps:

1. Secondary fermentation at atmospheric pressure (a tank valve is open) → bad smell from beer is removed
2. Secondary fermentation at overpressure (a tank valve is closed) → produced CO_2 is absorbed in beer – CO_2 content increases to c. 0,3 – 0,4 % (mass) → beer gains its frothing quality

Beer 10 % is in storage cellar tanks c. 3 – 5 weeks x CC tanks 2 – 3 weeks for both fermentation
Lager beer 12 % c. 2 – 3 months

< °C and > τ (but < 3 months) → > beer quality; longer time is not suitable (yeast autolysis)

Beer is tapped from several tanks together = beer blending (quality equalisation)
- a cellarman on the bases of laboratory tests and owns degustation (tasting) sets what tanks will be mixed

Sugar industry

Terms used in sugar industry technology

sheet 54

- Sugar = saccharose, sucrose (purity 100 %)
- Raw sugar – purity 97 – 98 % (3 – 2 % of non sugars)
- Affinated sugar, affinade – purity 98,5 – 99,0 %
- Refined sugar – purity 99,8 – 99,9 % (0,2 – 0,1 % of non sugars)
- Digestion Dg (%) – mass ratio of sucrose in sugar beet
- Saccharisation S (%) – mass ratio of dry matter in solution (juice)
- Polarisation P (%) – mass ratio of sucrose in solution (juice)
- Quotient of purity, purity Q (%) – mass ratio of sugar in dry matter
- Non sugars N_C (%) – mass ratio of non sugars in dry matter

$$P = Q * S / 100 \qquad S = P + N_C$$

In sugar technology are in calculations used co called "quantities per 1 ton of processed beet" or in % of beet = % ř.. The reason is a possibility of easy comparison of sugar factories with various capacities.

For example: Steam consumption is 30 % ř.

a) For a sugar factory with a capacity of 4000 t beet / d is actual steam consumption

   $(30 / 100) * (4000 / 24) = 50{,}0$ t / h

b) For a sugar factory with a capacity of 1500 t beet / d is actual steam consumption

   $(30 / 100) * (1500 / 24) = 18{,}75$ t / h

Sugar factory types

- raw sugar factory = sugar beet → raw sugar or affinade
- white sugar (refined sugar) factory = sugar beet → raw sugar → refined sugar
- white sugar factory with raw sugar purchase = sugar beet → raw sugar own + raw sugar purchased → refined sugar
- dry refinery = raw sugar purchased → refined sugar

Thick juice or liquor boiling to a massecuite (batch vacuum pans)

sheet 63

1) Vacuum pan evacuation
2) Drawing in a boil groundwork c. 300 mm above upper tube-plate (thick juice, liquor, syrup)
3) Boil groundwork concentration to a needed supersaturation (Kp ≈ 1,2) with further drawing in of thick juice and liquor (for A product) or thick juice and yellow syrup (for B product) or black syrup (for end product)
4) Crystals composition
   - seeding with a micro-seed (for 1 pan c. 300 ml of powdered sugar grain size c. 1 μm in ethanol)
   - adding of an artificial massecuite made from end product sugar = end product sugar mixed with thick juice (only for raw sugar or B sugar production)
   - hand made crystals creation = a quick pressure change results in a creation of big quantity small crystal nucleus (seeds)
   - batching = in the supersaturated sugar solution is added c. X00 kg of sugar (siftings from white sugar sorting sieves (for refined big crystals production)
5) Seed (small crystals) boiling up – each small crystal is a basis of a new growing crystal (crystals quantity in seeding and after boiling up have to be the same). When is Kp too > ”false grain (crystals)” form (boil powdering) → the false grain has to be dissolved in water or light juice (→ energy loses as the water has to be

once more evaporated); during boiling up are gradually drawn in thick juice or liquor and so is kept needed supersaturation Kp; boiling up ends when is level c. 1,5 m above upper tube-plate

6) Drying of boil – a massecuite (magma) = mixture of crystals and supersaturated solution is concentrated to c. 91 – 94 %; it has to contain crystals of needed size and has not to be sticky
7) Boil discharging – the massecuite is discharged in crystalliser where crystals for some time during cooling growth (part of sugar from solution passes to crystals → higher sugar yield)
8) Vacuum pan and piping steaming – hot steam removes rest of sugar solutions and crystals from heating tubes and other surface

Boiling time:
- A product (raffinade) c. 2,0 – 2,5 h
- B product or raw sugar c. 4 h
- C product (end product sugar) c. 16 – 20 h

→ fluctuation of steam (vapour) consumption in boiling plant (boiling house)

→ it is necessary to co-ordinate work of all vacuum pans in boiling plant

to be the total steam (vapour) consumption steady (x continuous vacuum pans)

Boiling process control:

- manually – (massecuite testing on glass (crystals size and quantity), fingers (stickiness) , sight glasses in vacuum pans)
- automatically – refined sugar according conductivity, end product according viscosity

Crystallisers

- time of massecuite ageing is X h;
- horizontal half-cylinders with band mixer (batch) or vertical cylinders (continuous);
- natural cooling from level or cooling tubes, discs etc.

Fully automated centrifuges ARO

– filling of a basket with massecuite at c. 100 rpm,
- run up to centrifuging speed, centrifuging of syrups at c. 1200 (1500) rpm
- washing-up (with condensate, syrup or steam) at c. 1200 rpm, effluent separation or not (white, green, yellow syrup),
- slow-down to ploughing speed,
- ploughing of sugar at c. 500 rpm;
- Σ c. 3 min.