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BY-PRODUCTS AND PROCESSING OF SUGAR BEET INDUSTRY

By

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DECLARATION

I hereby, declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been cited.

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Bijay Gurung Prague, 13th April, 20111

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Abstract

Sugar industry plays a vital role in the entire food industrial sector. It has co products along with different value added by-products. By-products of sugar beet industry were studied regarding wet pulp, dry pellets, lime sludge and molasses. Different parameters like sugar content, dry substance content, water loss during drying, pH etc. were observed and analysed in certain interval of time during the whole work. Similarly analysis on samples from various processing stations was also done. Especially the parameters like alkalinity and hardness during purification were the subject of interest during analysis as these are indicators that matters during achieving the high quality white sugar. Color, ash content, turbidity etc. were also analysed comparing it with the "European points" determining the standard suitable for human consumption.

Keywords: Sugar, sugar processing, sugar production, by-products, pulp, molasses, utilization of by-products etc.

Abstrakt

Cukrovarnický průmysl hraje důležitou roli v celém potravinovém sektoru. Je to vedlejší produkt s různými přidanými hodnotami. Odpady z odvětví cukrové řepy byly sledovány s ohledem na mokré řízky, suché pelety, vápenné kaly a melasu. Různé parametry, jako je obsah cukru, obsah sušiny, ztráty vody během sušení, pH atd. byly sledovány a analyzovány v určitém intervalu, během celé práce. Podobně byly také provedeny analýzy vzorků z různých zpracovatelských stanic. Zejména parametry jako alkalita a tvrdost při čištění byly předmětem zájmu v průběhu analýzy. Tyto indikátory jsou ukazatele, které přiblížily dosažení vysoké kvality bílého cukru. Barva, obsah popela, zákal atd. byly také analyzovány porovnáním s "evropskými body", kterými sestanoví standard vhodný k lidské spotřebě.

Klíčová slova: Cukr, postup při zpracování cukru, vedlejší produkty, řízky, melasa, využití vedlejších produktů-atd.

VIII. Appendix

List of Abbreviations

ADY- active dry yeast
BOD- biochemical oxygen demand
CLR - carbonation-lime residue
COD - chemical oxygen demand
DM - dry matter
DS - dry substance
EGSB - expanded granular sludge bed
GAC - granulated activated carbon
IC - internal circulation
IDY- instant dry yeast
MDC - molasses desugaring by chromatographic process
NADH- reduced Nicotinamide adenine dinucleotide NAD^+
NGS - new generation system
PhilBIO - Philippines bio-science
SAC - strong acid cation
SBP - sugar beet pulp
SBT - sugar beet tail
UASB - Upflow anaerobic sludge blanket
WAC - weak acid cation

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I. Introduction

Sugars are the building blocks of carbohydrates – monosaccharide, disaccharides and polysaccharides. The sugar which are generally sold in the market in white crystalline or powder form are disaccharides, which breaks down into two monosaccharide components – glucose and fructose (*Web 1*). Sugar, a disaccharide termed as sucrose, is the most plentiful and economic sweetener that can be found in many natural foods (e.g. fruits and vegetables) but can only be extracted economically from sugar beet and sugar cane *(Web 2)*. About 20% of the world's sugar supply is derived from sugar beet which is mostly produced in developed and industrialized countries like USA, France and Germany whereas rest 80% is derived from sugarcane mainly produced in developing countries like Brazil, China, India, Cuba, Mexico etc *(Web 3).* Areas covered by plantation of sugar beet and sugarcane throughout the world amount to about 25 million hectares of which 75% is covered by sugarcane and rest by sugar beet.

Sugar beet is unlike other agricultural crops in contrary that it is an industrial crop grown not for direct human consumption or for animal feed but as a raw material to be processed technologically in the factories *(Web 4).* Sugar beet has various importances in different sectors. It has positive impact on the economy of country where it is cultivated as it creates employments to local people and increases the country's income. The sucrose extracted from sugar beet is mainly utilized in food for human consumption. Approximately 70% of world sugar production is consumed directly in the country of production and the remaining 30% is traded with rest of the world. Sugar is the base for many industrial products including the food sector, pharmaceutical sector to energy provision and biotechnology *(Gwehenberger and Narodoslawsk 2007).* Trade in sugar is affected by very high volatility in prices compared with other commodities traded on world markets due to the different policies of individual countries and significant world sugar supplies. The characteristics of suffering from problems associated with storage and durability cause price fluctuations in sugar commodity *(Cock et. al., 2000 in Smutka et. al., 2011).* The sugar industry has evolved with profitability as the predominant objectives. In the present context, sugar industry is affected by consumption of various artificial sweeteners and glucose syrups in the market as its alternatives. It is again possible for sugar industry to relaunch the rational market share between different producers of sugarcane or sugar beets as they have high level of technologies introduced to optimize the energy saving, environment protection and quality assurance *(Mathlouthi 2000).*

Sugar has different uses such as sweetener, a preservative, a flavour enhancer, a bulking agents, a food for yeast to aid fermentation in baking and brewing etc *(Web 5).* It's by products are also utilized in higher level. Beet pulps are used as ruminants' nutrition and also equally used in the production and paper and boards. Filter cake is highly used as soil fertilizers as it is rich in nitrogen**.** Molasses has its own importance in the chemical and pharmaceutical industries for fermented products such as citric acid and its esters or can be combined with beet pulp to provide animal food, or are used as feedstock. Sugar molasses are of limited value for large-scale ethanol fermentation *(Web 6).*

1.1 World expansion and importance of sugar beet

Sugar beet is an herbaceous dicotyledonous plant that belongs to Chenopodiaceous (goosefoot) family. It has been cultivated for thousands of years ago but its potential as a source of sugar was not discovered until 1747. Its origin was supposed to be Mediterranean. The first factory was built in 1801 in Silesia. The beet sugar industry in Europe rapidly developed after Napoleonic Wars. In 1807, Britain blocked France from importing sugarcane from Caribbean that made France to develop sugar beet to eliminate France's dependency on foreign sources. After couple of years, small sugar beet factories started to operate in France, Belgium, Germany and Austria. By 1880, sugar beet replaced sugarcane as the main source of sugar on continental Europe. In United Kingdom the cultivation of sugar beet hasn't been started until mid of 1920. In United States, sugar beet production was started in 1832 in Massachusetts which was not successful and later on after forty years the sugar beet was produced successfully in California. In the starting time, growers were bound by a contract with the companies that they couldn't seed the beet without negotiations with the companies *(Web 7).*

1.2 Sugar beet Production, Yield and Area harvest

Table 1 Area harvest, yield and production of sugar beet (1989-2003)

	Year	1989-1991	1995	1998	2000	2003	%
World	Area harvest (ha)	8603	7832	6851	6141	5865	100
	Yield (kg/ha)	35171	33958	38415	39861	39812	100
	Production (1000 Mt)	302612	265963	263165	244780	233487	100
North America	Area harvest (ha)	571	598	605	572	558	9.51
	Yield (kg/ha)	44429	44131	50164	52985	51015	9.29
	Production (1000 Mt)	25399	26386	30363	30324	28445	12.18
South America	Area harvest (ha)	48	54	52	49	37	0.63
	Yield (kg/ha)	53723	69864	58945	67977	57578	0.65
	Production (1000 Mt)	2599	3746	3087	3361	2119	0.9
Asia	Area harvest (ha)		1325	1430	1117	1095	18.67
	Yield(kg/ha)		28043	33776	32977	29014	18.67
	Production (1000 Mt)		37168	48310	36844	31771	13.6
Africa	Area harvest (ha)	88	85	96	88	123	2.09
	Yield(kg/ha)	45503	45518	51417	62716	51451	2.09
	Production (1000 Mt)	4002	3863	4917	5519	6328	2.71
Europe	Area harvest (ha)		2993	4667	4314	4052	69.08
	Yield (kg/ha)		47187	37817	39114	40673	69.08
	Production (1000 Mt)		141222	176489	168732	164823	70.59

Source: FAO Production Yearbook 1995, 2000 and 2003

Table 2 Area harvest, yield and production in the selected countries of European Union (2007/08-2009/10)

	Production (1000 Mt)			Yield (t/ha)			Area harvest (1000 ha)		
Country	2007/08	2008/09	2009/10	2007/08	2008/09	2009/10	2007/08	2008/09	2009/10
Belgium	879.9	721.6	685.5	10.3	11.3	10.8	85	64	64
Denmark	353.9	397.1	337.4	9.7	11	10	39	36	34
Finland	101.3	69.4	87.5	6.3	5.1	5.8	16	14	15
France	4453.5	4096.6	4692	12.6	13	13.8	353	316	345
Italy	670.3	498.2	502.9	7.8	8.1	8.1	86	61	62
Germany	3901.4	3654.8	4224.6	10	9.9	11	391	370	380
The Netherlands	899.3	863.2	822	11.1	12.1	11.3	81	71	73
Portugal	13.6	0	0	9.5	na	na	1	na	na
Austria	365.4	409.5	416.8	8.4	9.5	9.5	42	43	44
Greece	78.4	157.4	158.7	5.6	7.2	6.9	14	14	23
Spain	562.3	607.9	598.8	9.3	11.8	11.7	60	51	51
Sweden	353.5	324.5	350	8.7	8.9	9	41	37	39
Great Britain	1049.2	1191.7	1250	9.9	11.8	12.4	106	101	101
Lithuania	125	68.5	99.9	7.4	7.9	6.9	17	9	15
Hungary	262.5	105.4	96.6	6.9	6.4	7.1	38	17	14
Slovenia	135.7	116.1	136.9	7.1	10.5	8.6	19	11	16
Romania	88.5	112.4	103.8	3.8	5.7	4.9	23	20	21
CzechRepublic	353.9	414.7	480	6.6	8.3	9	54	50	53
Total	16846.7	15344.9	16793.1	9.9	10.3	10.7	1699	1461	1540

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Source : <http://eagri.cz/public/web/file/58947/CUKR_06_2010.pdf>

1.3 World sugar production and consumption

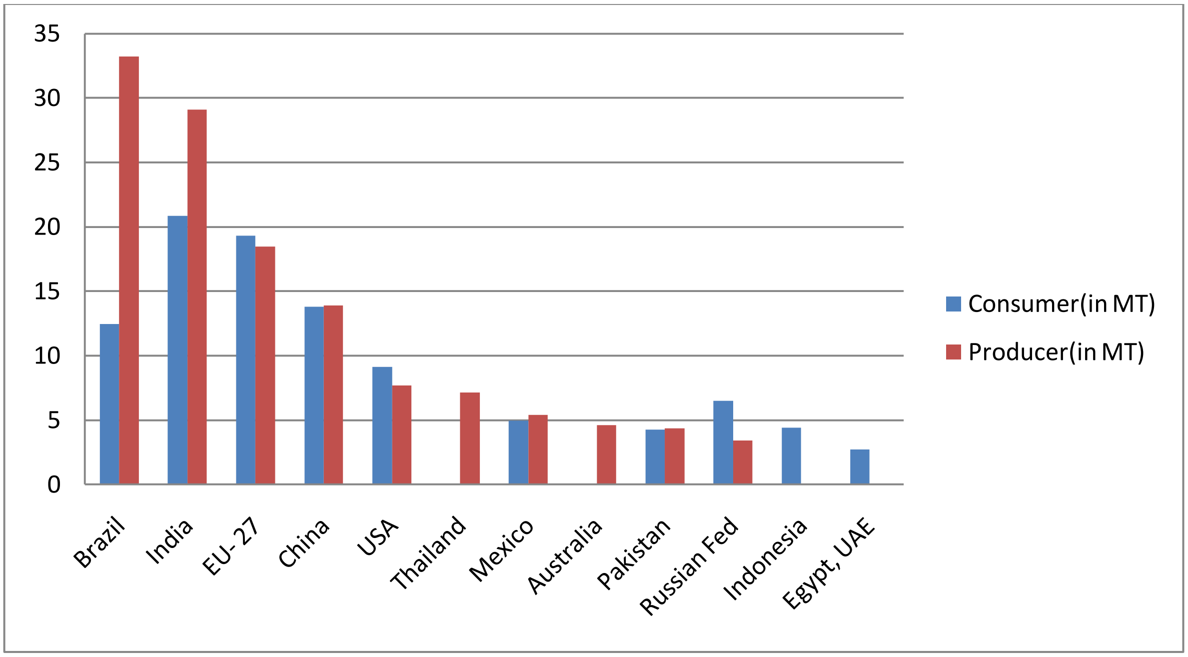


Fig 1: Ten largest sugar producers and consumers, 2007(in million metric tons, raw value)

Source: ISO Sugar Year Book 2008

Note: The statistics shown in the Year Book relate to centrifugal sugar only

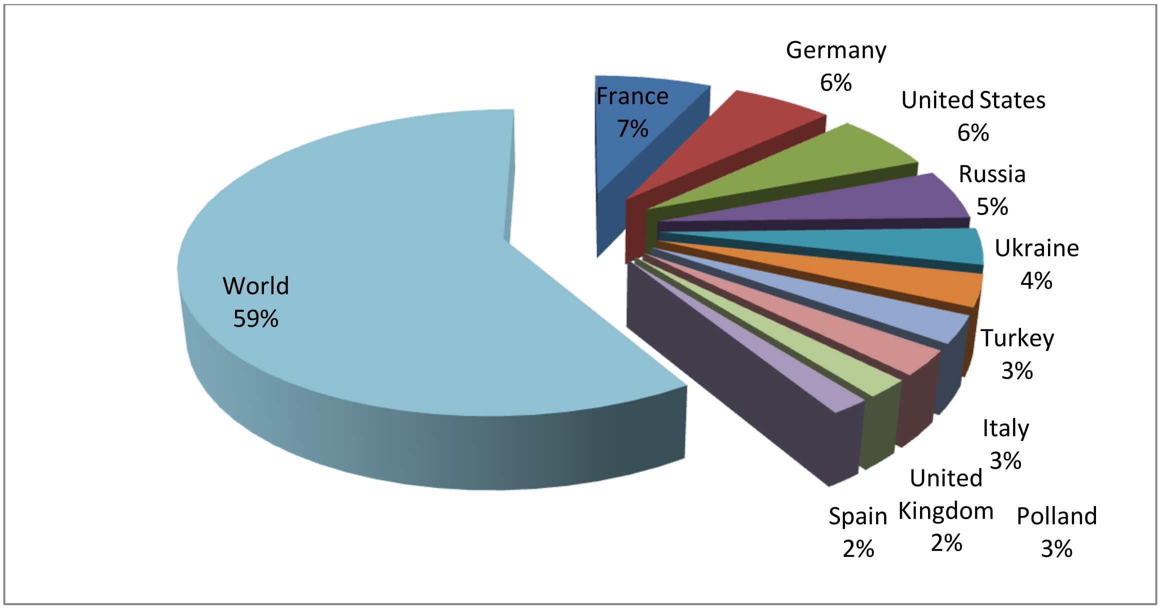


Fig 2: Top ten beet sugar producers-2005

Source: UN Food & Agriculture Organization (FAO)

II. Backgrounds

2.1 Botanical characteristics of sugar beet

Sugar beet is a biennial plant and belongs to species *Beta vulgaris*. It completes its vegetative cycle in two years. It needs first year to develop its swollen root where the sucrose remains and the next year it produces flowers and seeds. The stem remains very short in the first year and forms crown of the plant from which the leaves arise. Sugar beet plants have white conical root growing deep in the soil with only the crown exposed. The leaves are fairly smooth with a blade and petiole. The neck (hypocotyls) is the broadest part of the root *(Web 7)*. The sucrose is first synthesized in the leaves and then moved to the root cells through phloem. Sugar beet needs moderately cold climates but also can adapt itself in very cold and warmer climates. Sugar beet seeds are planted in spring and sugar beet is harvested in late fall or early winter when it is at maximum sugar content. Sugar beet grows in sandy loam, clay loam and peaty loam soil. Sugar beet grows best in a soil pH of 6.5 and higher *(Asadi, 2007)*. Harvesting is now entirely mechanical. Two types of harvesters are used: tractor-drawn and self-propelled. The sugar beet harvester chops the leaf and crown (which is high in non-sugar impurities) from the root, lifts the root, and removes excess soil from the root in a single pass over the field *(Web 8)*.

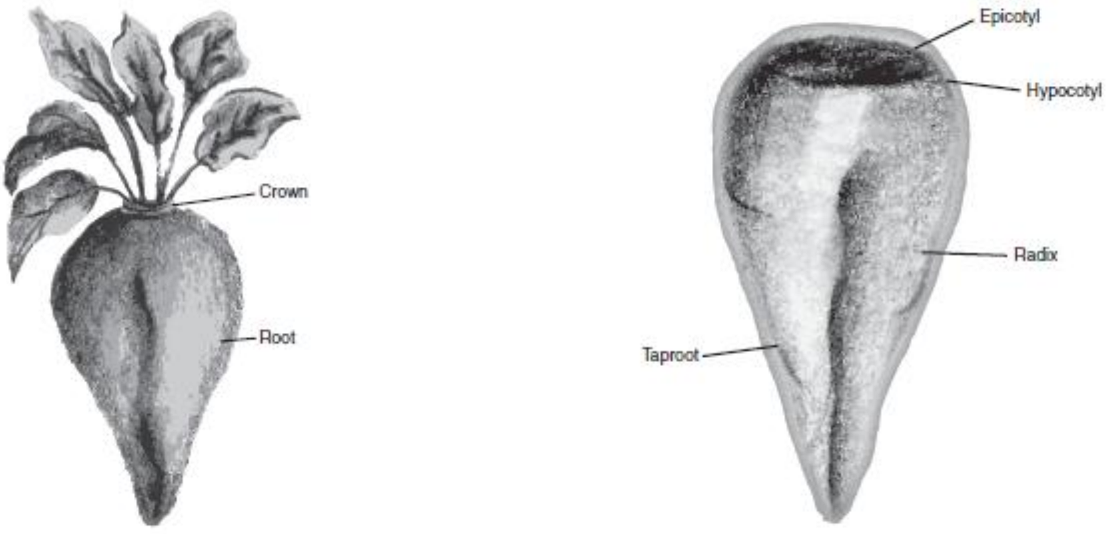


Fig 3: Different parts of sugar beet root

Source: Asadi, 2007

2.2 Processing of sugar beet to obtain refined sugar

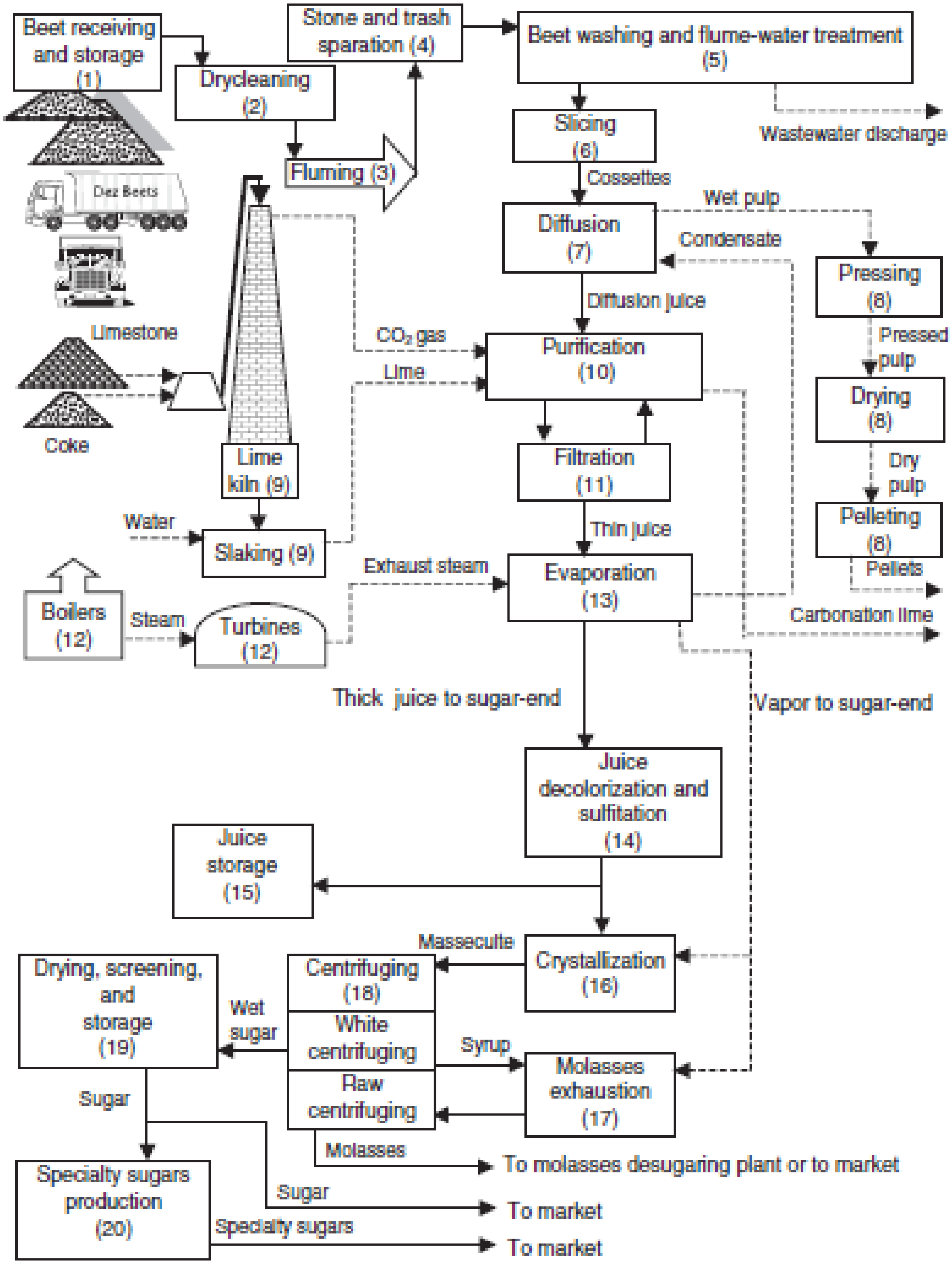


Fig 4: Flow diagram of a typical beet-sugar factory

Source: Asadi, 2007

Sugar beet processing involves several operations like diffusion, juice purification, evaporation, crystallization and sugar recovery from molasses. Each operation is involved in separating sugar (sucrose) from non sugars (non sucrose) which are considered as an undesirable substances *(Web 9).* Sugar beet, unlike sugarcane cannot be processed for *gur* or *khandsary* (*gur* is the most elementary form of sugar produced from sugarcane by cane growers in India just by boiling the raw cane juice to high concentration with all its impurities and cooling it to solidity and *khandsary* is the sugar formed by purifying the *gur* with improved techniques) and can only be used for vacuum pan sugar production *(Sharma, 1997).*

Here below is a brief description of the individual stations of the sugar factory as shown in the figure above.

2.1.1 Beet receiving, storing, washing and slicing

In the modern processing plants, sugar beets are delivered by trucks directly to the factory or outlying receiving or pilling stations. Tractor trailers are then used to haul the beets from the receiving stations to the factory. The beets are received in the factory by high speed conveying and screening systems. The beets received in the factory contains tare (impurities like soil, clay, stone, trashes i.e. leaves and weed) which should be separated before processing. The screening systems remove the loose dirt from the beets and pinch the beet tops and leaves from the beet roots. The function of conveyors is to transport the beets to the storage and then to the final cleaning and trace removal operations. Mostly the factories use flume to carry the beets to the feeder succeeding several steps like rock catcher, sand separator, magnetic metal separator, trash catcher *(Asadi 2007 and Wilson 2008).* Prior to extraction of sucrose from the beets, the cleaned and washed beets received through drag chain, chain and bucket elevator, inclined belt conveyor or beet pump are sliced into long thin stripes called cossettes in the beet slicer *(Web 9).*

2.1.2 Diffusion

Cossettes must be thin because thick cossettes need more time and higher amount of diffusion water. Uniform width of 3 to 6 mm thick, square or V shape and uniform length of 30 to 60 mm is highly preferable size for convenient diffusion. Sugar with non sugars is removed from the cossettes by soaking the thin beet strips in hot water (about 70˚C) in process equipment designed as a diffuser. This diffuser may be a series of tanks or a single, large tank in which the beet slices are moved counter-current to hot water. Fresh hot water first reaches the cossettes from which the most sugar is taken and then moves, with its temperatures carefully controlled, through a series of compartments in a direction opposite to the movement of the cossettes. As it progresses through the diffuser, the liquid removes additional sugar from the chips and finally contains enough sugar to be called raw juice (with 85 to 88% purity) *(Web 10).*

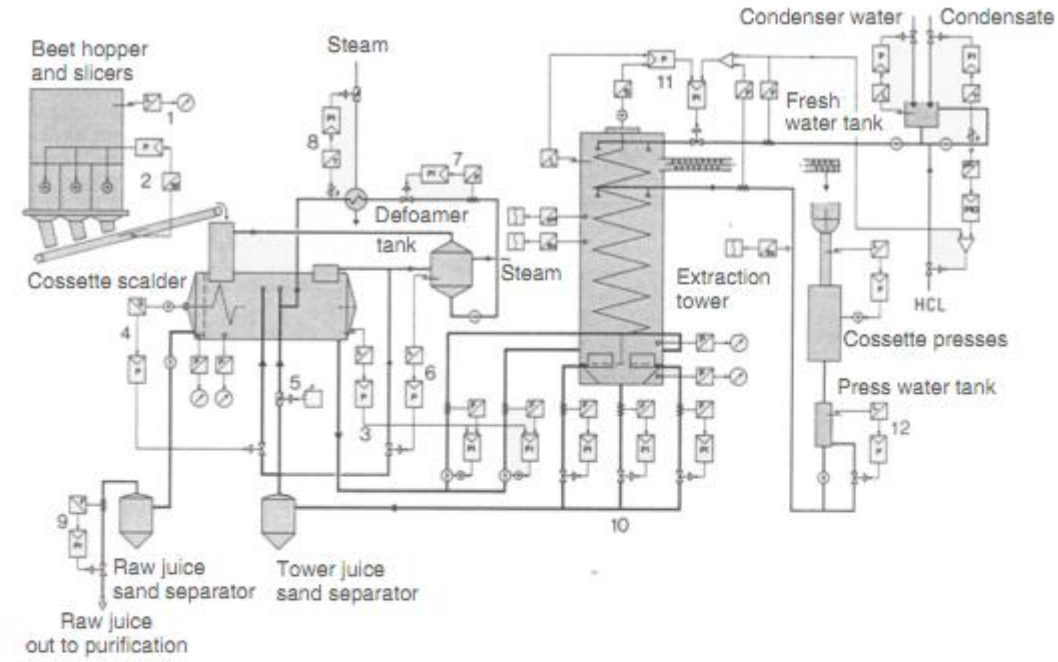


Fig 5: Diffusion process in the juice extraction station

Source: Web 11

As shown in the figure above, the cossettes are heated and denatured at the scalder and passes to the extraction tower as a cossettes juice mixture. The constant feed to the extraction tower is controlled by the loop designed. The foam from the ventilation grille of the cossette scalder is fed to the defoamer tank and precipitated through steam. It is heated to 80˚C in a temperature control loop before pumping back to the cossette scalder. The raw juice is then discharged from the cossette scalder through a front screen at the cossette input side. The juice volume drawn off is controlled by a flow control loop *(Web 11).* The wet pulp discharged from the extraction tower is pressed and the press water is reintroduced to the extraction tower *(Web 12).*

2.1.3 Juice purification

This operation is the most important operation among all and oftenly considered as the heart of sugar factory. The juice obtained from diffusion process generally has overall weight of 105-130% of the weight of the total raw beet materials processed which contains about 82-85% by weight water, 13-15% by weight sugar and 2-3% by weight dissolved/colloidal non sugar impurities *(Toth et. al., 1996).* This diffusion juice should be purified in order to remove the significant portion of nonsucrose fraction from the juice. The partially purified juice exhibits improved subsequent processing yields a higher recovery of crystallized product and improves product quality with respect to colour, odour, taste and solution turbidity. The purification of diffusion juice involves mainly two steps; liming and carbonation. The raw juice is heated to high temperature (about 86˚C) and a solution/suspension of calcium oxide and water (milk of lime) is added to the juice to adsorb or adhere to the impurities in the mixture. Then carbon dioxide gas is allowed through the juice to precipitate the calcium oxide as calcium carbonate. This step is the foundation of conventional purification scheme and commonly called first carbonation *(Kearney et al., 1995).* In conventional purification scheme, liming is done in two phases i.e. pre-liming (small amount of lime about 0.2 to 0.7% on beet is added to the juice to achieve the alkalinity of about 0.15% CaO and about 8.5 pH value) and main liming (more lime is added about 1.0 to 2.0% on beet to obtain pH of about 12.0 to complete the reactions of non sucrose with lime) *(Toth and Conway 1989 and Asadi 2007).*

Liming:

$$Ca(OH)_2 + Na_2C_2O_4 \rightarrow CaC_2O_4\downarrow + 2NaOH$$

Carbonation:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O$$

The calcium carbonate precipitate usually referred as mud is removed by the means of settling clarifiers or by appropriate filters which contains about 20 to 30% of nonsucrose contents (invert sugar, colloids and coloring substances) of the raw juice. The first carbonation juice is most commonly sent to the second carbon dioxide gassing tank for second carbonation without further addition of lime in order to reduce the level of calcium present by precipitating calcium ions as insoluble calcium carbonate. The second carbonation juice is then filtered to separate the calcium carbonate precipitate. The filtered juice is now referred as thin juice (purity about 85 to 92% and pH of 8.8 to 9.0). Conventionally, the calcium oxide and the carbon dioxide are produced by heating limestone (calcium carbonate) utilizing coke or natural gas as a fuel in a high temperature kiln in the sugar beet factory. There are also other several processes proposed for purification of raw juice which includes defeco-carbonation (addition of lime and carbon dioxide gas simultaneously in a continuous basis), microfiltration and ultrafiltration those involve the use of membranes to separate materials of differing molecular weight from the raw juice and ion exchange method *(Kearney et al., 1995).*

2.1.4 Juice softening process

Softening is the defined as the process of removal of hardness determining ions which are mainly calcium, magnesium and, to a lesser extent, iron and manganese from solution *(Thompson, 1994).* Thin juice always contains certain amount of hardness (calcium and magnesium salts) which should be removed to prevent scale formation and to achieve more efficient crystallization and sugar recovery. Hardness content of 50 to 200mg/100g DS is normal. Mostly sugar factory uses juice softening process based on the ion exchange resin (porous-insoluble polymer produced by polymerisation of styrene and small amount of divinylbenzen). There are several softening techniques available to the sugar industry. Gyrllus process is the one which use SAC resin to soften the juice. This method is good enough for only conventional factories because it cannot produce molasses with low hardness that is necessary to feed directly to molasses MDC. To compensate it, there is another system NGS with both advantages.

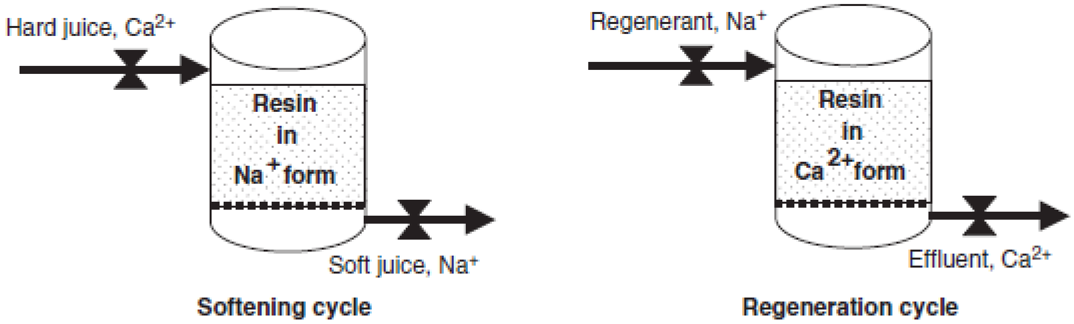


Fig 6: Softenening and regeneration cycle using resins

Source: Asadi, 2007

The functional group in the resins are sulphonic $(SO_3H)^-$ and carboxyl (COOH) groups. In juice softenening process, both SAC resin and WAC can be used for exchange of cations in the juice. The softening process involves exchanging calcium and magnesium ions with sodium ions of the resin. When resins is completely in calcium or magnesium form, it is considered to be exhausted *(Thompson, 1994)* and should be regenerated with a solution containing sodium, such as salt solution (NaCl) or NaOH. In a case of juice contains high hardness, it can be soften by two step softening process that involves pretreatment with soda ash (Na_2CO_3) to reduce the amount of hardness to 100 to 150 mg Level and treatment with the WAC resin to reduce the hardness to the desired level of about 17 mg. This process has disadvantage of being soda as a strong melassigenic substance *(Saska and Lancrenon 1995 and Asadi, 2007).*

2.1.5 Thin juice evaporation

Evaporation of juice is done by multi evaporators which invention dates back along with the history of sugar technology. Thin juice with about 15% DS is heated in the thin-juice heaters to about 90˚C. Then it is pumped into the evaporators to increase its concentration to about 60% DS. The thermal energy is supplied by boilers in the form of steam with high pressure (240 to 380 KPa). In sugar factory, evaporation is done under low vacuum which lowers the boiling point of the juice saving the energy. In multiple-effect evaporation, the partially concentrated juice leaving the first effect acts as a feed to the second effect, and the vapor produced from the first effect is used as a heating medium to heat the second effect. After additional concentration, the product from the second effect becomes feed for the third effect, and so on. Vapor from the last effect goes to a condenser. Finally, concentration of juice in the evaporator outlet i.e. thick juice is obtained which is desired to be as high as possible reaching 72-75%. To avoid the deterioration of juice quality and especially its pH and colour, the juice temperature at inlet should not exceed 128°C and thick juice temperature at outlet should be not lower than about 90°C. Generally in advanced evaporator station with six or seven stages, the average temperature interval is 6-7 K. However, as the boiling point elevation ranges from 0.5 K in the first stage to 7 K in the final one, the effective temperature interval is only 4-5 K *(Urbaniec, 2003).*

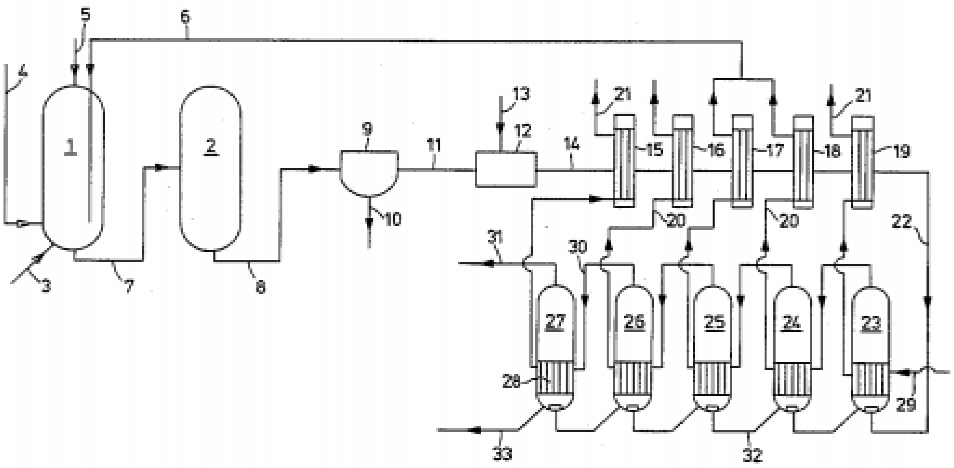


Fig 7: Evaporator station

15-19 pre heaters, 20 inlet pipe for indirect heating by the means of gaseous medium, 21 discharge pipe for spent heating medium, 23-27 evaporators, 30 inlet pipe for heating medium, 31 discharge pipe connected to vacuum source, 29 inlet pipe for the steam and 33 discharge pipe for thick juice.

Source: Patent No: 4534800

Generally, there are two types of evaporators according to shape of their heat transfer surface. They are tube and plate evaporators and again are categorized as thin falling film and thin rising film.

2.1.6 Juice decolorisation

The colored compounds formed during processing of beets to form juices and syrups in several stages are polymers with different molecular weights, structure and properties. These compounds are formed in the process as a result of sugar degradation reactions, pH changes, thermal effects and reactions between amino compounds and carbohydrates *(Coca et. al., 2004)*. Alkaline degradation of invert sugars and melanoidin (Maillard reaction product formed by the reaction of monosaccharide and carbonyl compounds with amino acids) formation results in the formation of colorants in beet processing, whereas cane colorants are mainly plant pigments associated with polysaccharides *(Godshall,Vercellotti and Triche 2002 in Coca et. al., 2004)*. Bohm and Schafer (1969) has described about the decolourisation of beet juice using ion exchange resins on the industrial scale *(Lewis, 1996)*. The resins used for decolourisation are strong base anion resins in the chloride form. The process is quite similar to ion exchange process described in softening of juice.

Decolourisation of sugar beet juice can be done by using GAC which has a function of impurities adsorption mechanism. It has enormous surface area to mass ratio that helps it to purify liquids or gases by mere contact. The adsorption mechanism of GAC includes physical adsorption processes that do not involve formation of chemical bonds e.g. Van der Waals etc which allows it to simultaneously capture impurities that have very different properties, e.g., differences in charge, electric dipole moment, polarizability, hydrophobicity, molecular weight, etc *(Bento et al., 2008)*.

Another method of decolourisation is sulphitation in which sulphur dioxide is introduced into the juice. Carruthers et. al., (1955) in Davis (2001) found that sulphur dioxide is more effective at suppressing colour formation than reducing colour already formed.

2.1.7 Syrup crystallization

Crystallization in sugar industry is carried out involving evaporation and cooling processes. These operations are carried out in cooking or boiling apparatuses and in crystallizers or mixers.

In boiling the syrup, the certain parts of water molecules in the syrup are evaporated and seed crystals are introduced to maintain the supersaturation *(Grandadam, 1967).* The crystals are given time to grow. Seeding of the solution is normally utilized as it provides nucleation centres around which the actual crystal growth primarily occurs. High crystal yield with a uniform structure and a narrow crystal size distribution can be obtained if great number of seeds are introduced into the syrup as it minimizes spontaneous nucleation (the formation of crystals with or without seeding at a given supersaturation coefficient) *(Eriksson et al., 2004).*

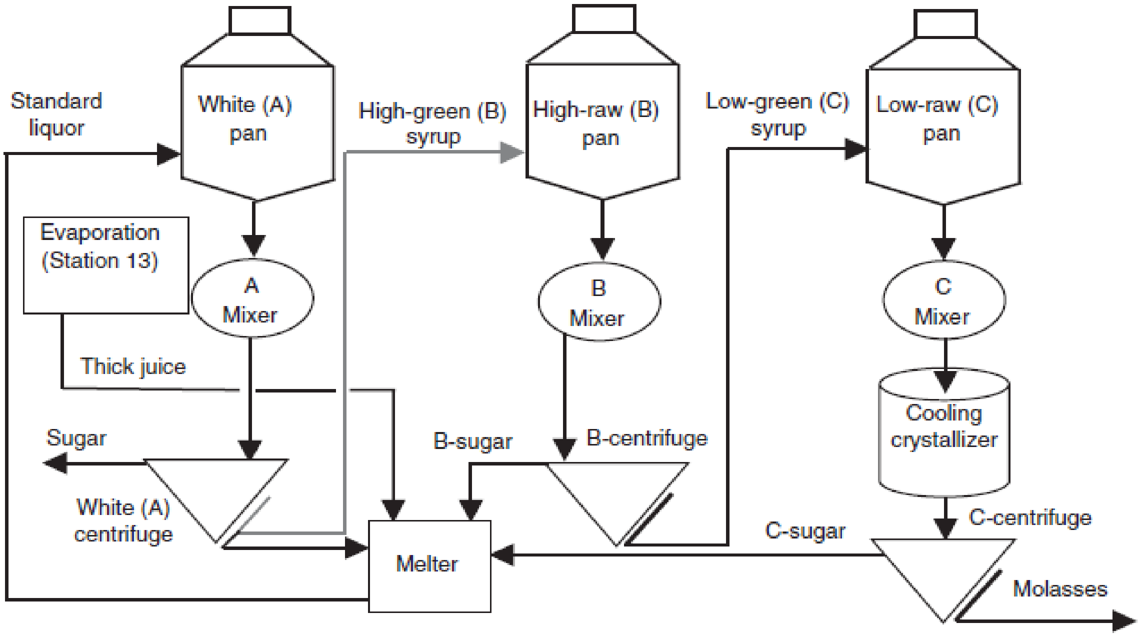


Fig 8: Crystallisation of sugar

Source: Asadi 2007

The boiling is stopped after the crystals reach the desired size and the white (A) massecuite is discharged to the mixer. It is centrifuged in the centrifuges to separate crystals from mother liquor. The crystals obtained are white `A' sugar and the syrup is termed as high green (A-green) syrup (purity about 86%). The sugar is washed with hot water and such wash syrup is pumped to the melter. High green syrup is seeded and fed to the second crystallisation stage which results in formation of high raw sugar B and low green (B-green) syrup (purity about 76%). High raw sugar is sent to the melter and low green syrup is fed to the third crystallisation stage which results in formation of low raw C masssecuite. It is then discharged to the mixer and sent to cooling crystallizer where it is kept for 2 to 3 days for proper crystallisation. After the holding time, it is sent to centrifuge into low raw C sugar and the remaining is the molasses. Low raw sugar is then sent to the melter where it is mixed with high raw sugar, wash syrup and the thick juice to produce the standard liquor as a feed to the first crystallisation stage. The by-product of the crystallisation process is the molasses from which extra sugar can be extracted with MDC *(Asadi, 2007).*

2.1.8 Sugar drying, storing and packing

Drying is the process of removing moisture from the wet substance by using heat. The wet sugar obtained from the centrifugal process contains about 0.1 to 1% moisture content and a temperature of about 60˚C. Sugar industry utilises various types of sugar drying systems depending upon the temperature, air flow direction and volume etc. Some of dryers used are belt type dryer, tray dryer etc *(Bostock, 2009).* Most of the factories today use drying and cooling in the same equipment because of the high heat content (enthalpy) of wet sugar but some sugar factories has sugar coolers that uses conditioned air to cool the sugar. The sugar is dried and cooled to the moisture content of 0.05% and a temperature below 35˚C. Then the dried sugar is sent for screening to separate the undersized and oversized sugar particles and finally it is sent the sugar silo for storage or processed in the specialty sugars *(Asadi, 2007).*

2.3 Wastewater treatment

There exists number of sources of wastewater in the sugar beet industry. Among these, flume water that is used to wash the beets constitutes about 70% of the total volume of wastewater generated in the factory. The process wastewater originates from the flushing of exhausted cossettes from the diffusion cells and the partial dewatering of the exhausted pulp *(Web 5).* According to ATV (2004) in Jordening and Winter (2005), there are several fractions of wastewater in sugar factory with different specific amount and COD load. They are cleaning water, pulp press water, water from ion exchange unit, surplus condensates etc. The most important wastewater components from sugar beet industry are the high organic loads derived from the sugar where the amounts of nitrogen and phosphorus are comparatively low. This wastewater can lead to contamination of land and water if not managed properly. This could be the threat to environment but in the mean time there are also several methods for the treatment of wastewater to utilise it in different sectors. Commonly practised methods are soil treatment, long term batch processing and small scale technical processes usually consists of anaerobic pre-treatment and aerobic secondary treatment. Agricultural soil treatment is the basically focused on the utilisation of nutrients and water. In this treatment, the wastewater is used for irrigation of land. Payam et. al., (2009) states that the application of sugar beet industrial wastewater didn't have potential to cause the problems in soil structure but could cause some physical properties of soil like infiltration. In long term batch processing, the wastewater is discharged into a sealed pond. The batch depth should be more than 1.2m if not then the COD concentration should be reduced to 300 mg/l. It requires large area and produces noxious odours in spring which are the disadvantages of this management system. Recently due to the sustainability and cost effectiveness, anaerobic treatment of wastewater is used in most of the sugar industries. It has various advantages over conventional aerobic treatment systems like less sludge production, production of methane gas at the theoretical value of 3.8 KWh/kg COD removed, no use of fossil fuels etc. There are several technologies for anaerobic treatment of wastewater like granular sludge based technologies and super high rate technologies. At present the widely used reactors are super high rate EGSB and IC because of vast growing experience and availability of indispensible seed material i.e. methanogenic granular sludge *(Web 1).* The research project done by PhilBIO concludes that the utilization of UASB technology through pilot plant design optimizes the wastewater treatment and methane gas recovery while limiting the impacts of sulphates which may cause problems in the digesters on the physical structure of the plant *(Stewart, 2004).* According to them 100% biogas can be utilised for the generation of electric power.

2.4 Industrial sugars and their characteristics

a) Standard raw sugar

It is the sugar obtained from crystallization of the concentrated juices of sugarcane or sugar beet. It has a crystal size of 0.8 mm and is covered by a film of molasses which gives it the brownish color. It has polarisation content of 97.5-98.0%. It is a raw material for the production of refined sugar.

b) Plantation white sugar

It is same as standard raw sugar but white in color which is achieved by the sulphitation process in the purification procedure. It has crystal size of 0.4-0.5mm and has polarisation content of 99.4-99.6%. It is used for domestic consumption and some industrial uses.

c) Refined white sugar

It is the sugar obtained from crystallisation of sucrose from a low color liquior obtained by dissolution, purification and decolourization of dissolved raw sugar. It has crystal size of 0.4-0.5mm and is white in color with polarisation content 99.9 %. It is consumed in the market by human and also used for various industrial purposes.

d) Powdered sugar and etc

It can be obtained from sugar dryers subsequent to the production of white or refined sugar or can be produced by crushing sugar crystals. It has crystal size of 0.15mm and polarisation content of 99.0%. It is highly used in bakery products, cereals and confectionary *(Delgado and Casanova 2001).*

2.5 Utilization of refined sugar

Refined sugar is consumed mostly by human directly and in food industrial sector. The refined sugar combines refined cane sugar, refined white sugar, crystalline white sugar, natural refined sugar, healthy white sugar and processed white sugar.

2.5.1 Human consumption

Refined sugar is used by human being for households. It accounts almost one third of the total consumption of sugar. According to the study by Ismail et. al., (1997) there is evidence that sugar (sucrose) use was increasing in China, India, and Southeast Asia. In South and Central America (except Haiti) sugar use was either equivalent to or higher than that in most developed societies. Many central African countries consumed less than 15 kg of sugar/person/year. Total sugar consumption in the European Union is dominated by member countries with large populations like Germany, France and the United Kingdom. Per person consumption, however, is highest in Denmark and Belgium–Luxembourg, at over 50 kilograms (raw value) a year *(Sheales et. al., 1999).*

2.5.2 Industrial sector

Refined sugars are highly versatile and can be used as general sweeteners in a variety of applications and industries. They are typically used in beverage, baking, confectionery, pharmaceutical, dairy, brewing, canning and ice-cream manufacturing industries. The confectionery and pharmaceutical industries demands a high quality refined sugar with the optimum colour and purity. The functionalities like enhancing flavour, bulking agent, quick dissolving, improving texture etc made sugar so demandable for those industries.

2.6 By-products of sugar industry

A by-product is a secondary product obtained from the manufacturing process, or chemical reaction and is not primary product which is desired. There can be one or more than one by products during manufacturing process. While talking about sugar manufacturing, there is more than one by product. It is better to produce many value added products by diversification and utilizing the by-products of the sugar industry, instead of depending on just one product i.e. sugar *(Paturau, 1982; Singh and Solomon, 1995; Godshall, 2004 in Yadav and Solomon 2006).* Utilizing the by-products plays vital role in minimizing the pollution hazards which has positive effects in environment. It has also the significant impacts on the economy as the waste products are converted to the value added products *(Yadav and Solomon 2006).* The by-products of sugar beet industry are:

a) Sugar beet pulp (SBP) / sugar beet bagasse
b) Sugar beet tail (SBT)
c) Carbonation-lime residue (CLR)
d) Molasses

2.6.1 Sugar beet pulp (SBP)/ sugar beet bagasse

Beet pulp is the residue of the sugar manufacturing especially the residue after diffusion process which is the low cost by product. While processing the sugar beet for sugar production, we can get 25% of beet pulp on average. The native sugar beet pulp particle size varies from 0.3 to 0.5 cm *(Kryvoruchko et. al., 2008).* Wet pulp, containing about 90% water is pressed using double screw presses to reduce the moisture content to 75%. The pulp can be further dried to lower its moisture content to about 10%. Sometimes molasses can be mixed with the pulp before drying or molasses can be mixed during pelletizing (in order to reduce bulk density and for better transportation) the dried pulp *(Kent, 2003).*

Table 3 Nutrients content of SBP

XP, %DM	XL, %DM	XF, %DM	XA, %DM	XX, %DM	N, %DM	C, %DM	Sugar, % DM	GE, MJ/kg VS	C/N	pH	DM, %FM	VS, %DM
8.7	1.5	19.5	5.5	64.9	1.5	49.4	7.0	20.0	32.9	3.5	30.4	94.5

XP =crude protein, XL=crude lipids, XF =crude fibre, XA =crude ash, XX =N-free extracts, N =nitrogen, C= carbon, GE =gross energy, DM =dry matter, FM =fresh matter, VS =volatile solids.

Source: Kryvoruchko et. al., 2008

2.6.2 Sugar beet tail (SBT)

The SBT is the lowest part of the sugar beet which is cut off from the beet during the cleaning process. During sugar production from sugar beets, the average sugar beet tail that can be accumulated is about 5% of the total beets processed. The native SBT had a particle size between 3 and 5 cm and can be minced in a mixer to a particle size of 0.1–0.3 cm in order to get good mixing characteristics in the fermenters *(Kryvoruchko et. al., 2008).*

Table 4 Nutrients content of SBT

XP, %DM	XL, %DM	XF, %DM	XA, %DM	XX, %DM	N, %DM	C, %DM	Sugar, % DM	GE, MJ/kg VS	C/N	pH	DM, %FM	VS, %DM
12.8	2.5	18.9	28.7	37.1	2.3	34.5	4.0	21.9	15.0	4.2	11.8	71.3

XP =crude protein, XL=crude lipids, XF =crude fibre, XA =crude ash, XX =N-free extracts, N =nitrogen, C= carbon, GE =gross energy, DM =dry matter, FM =fresh matter, VS =volatile solids

Source: Kryvoruchko et. al., 2008

2.6.3 Carbonation-lime residue (CLR)

CLR (lime cake) is the by-product of raw juice purification process. The carbon dioxide gas is passed through the heated and limed juice to form calcium carbonate that absorbs insoluble impurities and some amount of soluble impurities too. Generally, it is termed as first carbonation slurry in sugar industries as it is slurry with suspended solids after first carbonation process. Then the solids in the slurry are separated using clarifiers (settlers based on gravity sedimentation principle) or thickening filters to result the carbonation mud. The clarified juice constituents 75% of the first carbonation slurry and the remaining are the carbonation mud. In sugar industries equipped with carbonation mud recycling, 50-60% of the carbonation mud is pumped back to the prelimer and the rest is further thickened to lose its moisture content with the help of membrane filter presses or rotary drum filters. The amount of solid content of the CLR varies according to the types of filters used. The CLR produced by rotary drum filters contains 50% of the solids so usually they are kept in the lime pond to reduce the moisture content *(Asadi, 2007).*

2.6.4 Molasses

Molasses is a co-product of sugar production in sugar industry, both from sugar beet as well as from sugar cane, and is defined as the runoff syrup from the final stage of crystallization, from which further crystallization of sugar is uneconomical. Beet and cane molasses has various significant differences regarding their constituents like nitrogenous compounds, ash, vitamins and fermentable sugars *(Nasab et. al., 2010).*

2.6.4.1 Composition of molasses

The data on the sugar beet molasses are the averages from two samples each of Dutch and French molasses from 1990 campaign and the U.S beet molasses data are the averages from five factories belonging to American Crystal Sugar over the 1991 season.

Table 5 Average composition percentage of European and U.S beet molasses

Component	European beet molasses	U.S beet molasses
Water	16.5	19.2
Sucrose	51	48.9
Glucose + Fructose	1	0.5
Raffinose	1	1.3
Organic non sugars	19	18
Ash	11.5	12.1

Table 6 Ash Components

Components	European beet molasses	US beet molasses
Silicon dioxide (SiO_2)	0.1	-
Potassium oxide (K_2O)	3.9	6.4
Calcium oxide (CaO)	0.26	0.21
Magnesium oxide (MgO)	0.16	0.12
Phosphorus Pentoxide (P_2O_5)	0.06	0.03
Sodium oxide (Na_2O)	1.3	1.6
Iron oxide (Fe_2O_3)	0.02	0.03
Aluminum oxide (Al_2O_3)	0.07	-
Carbonate (CO_3)	3.5	-
Sulphates as SO_3	0.55	0.74
Chlorine (Cl)	1.6	0.8

Table 7 Vitamins (mg/100 g)

Components	European beet molasses	US beet molasses
Thiamine (B1)	1.3	0.01
Riboflavin (B2)	0.4	1.1
Nicotinic acid	51	8
Ca-pantothenate (B3)	1.3	0.7
Folic acid	2.1	0.025
Pyridoxine-HCL (B2)	5.4	-
Biotin	0.05	-

Source: Table 4, 5 and 6, Vogel et. al., 1997

2.6.4.2 Properties of molasses

There are several physical characteristics of molasses which should be kept in account while processing of it in different sectors. These properties are of more or less importance for those industries which process the molasses which were described in early times by Oldbrich (1963).

a) Viscosity of the molasses

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. It describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. The SI physical unit of dynamic viscosity is the pascal-second (Pa·s), (equivalent to $N \cdot s/m^2$, or kg $(m \cdot s)^{-2}$). The viscosity of the individual molasses depends on the temperature and concentration. According to Winkeler (1954) in Oldbrich (1963) at a temperature of 10˚C, the viscosity of the factory molasses may be so great that it can no longer be determined by the means of outflow viscosimeters or other similar measuring instruments. Breitung (1956) in Oldbrich (1963) noted that two molasses of the same viscosity at a given temperature, but of different densities molasses will have approximately the same viscosity at all temperatures.

b) Specific heat of the molasses

Specific heat or heat capacity of a substance gives the number of heat units or calories required to raise the temperature of 1 kg substance by 1˚C at atmospheric pressure. At same temperature the specific heat of molasses is lower than that of pure sugar solution. The lower the purity quotient the lower the specific heat of the molasses i.e. at constant concentration and temperature the specific heat falls with decreasing purity *(Oldbrich, 1963).*

c) Contraction of molasses:

The property of solid or liquid substances to decrease in volume when dissolved in or diluted with water is called contraction. The contraction of impure sucrose solutions is greater than of pure sucrose solutions. The contraction of molasses is greater than that of a sugar solution of the corresponding density. No strict rules can be given regarding the difference between the contraction of molasses and that of pure sugar solutions. Schander, Partale (1955) and Paar (1935) in Oldbrich (1963) during their research observed that the contraction differences were irregular and varied with the density, specific gravity, the purity of the molasses and the composition of the non sugars.

d) Coefficient of expansion of molasses

Liquids have cubical coefficient of expansion which gives the relative change in volume per degree rise in temperature. No useful data are given in literature concerning the temperature volume relation for impure sugar solutions and molasses. This is appropriate to apply to molasses the values obtained for solution of sucrose *(Hirschmuller in Honig (1953), Oldbrich (1963))*. When hot molasses are handled, it is essential to take in account the coefficients of expansion to calculate the amount of solids.

e) Elevation of the boiling point of molasses

The boiling points of cane and beet molasses of varying concentrations are practically the same. They are always higher than those of corresponding pure sucrose solutions.

2.6.4.3 Production of molasses

Around 50 million tonnes of molasses are produced globally. The shares of cane and beet molasses in the whole production of molasses contributes in the similar way as in the production of global cane sugar and beet sugar i.e. 75% for cane molasses and 25% for beet molasses. In 2007, the Confederation of EU Yeast producers (COFALEC) expected that 80% of the molasses would be captured by bio-ethanol industry. Before the sugar reform, EU was responsible for 4 to 5 million tons of molasses. France, Germany and Poland are the EU's biggest producers of molasses as they are ones to produce sugar in largest amount *(Web 13)*.

Table 8 Molasses production in the U.S As Compared to World Production

Year	U.S (in million metric tons)	World (in metric million tons)
1978-79	2.02	32.3
1979-80	1.93	29.7
1980-81	2.06	30.9
1981-82	2.12	34.8
1982-83 (est.)	2.02	34.4

Source: Web 14

Table 9 EU[1] molasses production in thousand tones, 2003-2007

	2003	2004	2005	2006	Average annual change in %
France*	1,015	924	n.a	n.a	-9.02
Germany**	839	841	842	n.a	0.23
Poland	483	380	428	425	-4.1
Spain	442	n.a	n.a	n.a	-
Italy	508	382	354	552	2.8
Belgium**	196	231	212	n.a	4.03
UK	241	238	194	167	-11
Czech Republic	153.10	140.21	130.99	110.00	-10.5
Hungary	96	95	139	115	6
Austria**	121	115	116	n.a	-2.13
Greece**	131	88	95	n.a	-153
Denmark**	106	90	89	n.a	-8.43
Slovakia	59	59	72	74	7.8
Sweden	82	74	65	67	-6.4
Ireland*	41	45	n.a	n.a	9.82
Lithuania	47	41	35	28	-16
Portugal	31	24	31	25	-6.9
Romania	35	35	29	41	5.5
Finland**	23	21	23	n.a	-0.43
Latvia	26	22	19	16	-15
Bulgaria	2	0	1	1	-20
Estonia	0	0	0	0	-
Luxemburg	0	0	0	n.a	-
Malta	0	0	0	0	-

Source: Eurostat, 2009

[1] No data available for The Netherlands, Slovenia and Cyprus

[*] Average annual change between 2003 and 2004

[**] Average annual change between 2003 and 2005

The source of data for Czech Republic is <*http://www.cukr-listy.cz/lc-statistika.html*>

Data presented just above include both beet molasses as well as cane molasses. However the sugar produced in EU is mostly from sugar beet, so most of the above mentioned are beet molasses *(Web14).*

Table 10 Total domestic use of molasses in EU, 2003-2006 in thousand tones

	2003	2004	2005	2006	% industrial use
France	1,303	1,286	n.a	n.a	68 (2004)
Spain	757	n.a	n.a	n.a	50 (2003)
Germany	699	821	667	n.a	17 (2005)
UK	818	783	648	553	38 (2006)
Italy	0	0	550	687	n.a
Belgium	461	509	406	n.a	100 (2005)
Ireland	293	251	n.a	n.a	43 (2004)
Hungary	111	171	208	187	98 (2006)
Austria[1]	145	137	154	n.a	62 (2003)
Denmark	237	253	124	n.a	60 (2005)
Sweden	114	116	114	104	29 (2006)
Poland	171	177	107	190	85 (2006)
Romania	51	74	89	49	89 (2006)
Portugal	96	97	87	91	40 (2006)
Greece	88	88	72	n.a	69 (2005)
Finland	27	21	28	n.a	7 (2005)
Bulgaria	22	24	21	34	85 (2006)
Latvia	7	9	17	8	n.a
Lithuania	12	13	11	7.9	0 (2006)
Estonia	6	6.5	4	7.9	78 (2006)
Slovakia	2	1	0	0	-
Luxemburg	1.1	0.8	0	n.a	-
Malta	0	0	0	0	-

Source: Eurostat, 2009

[1] 30% of the domestically used molasses is unaccounted for, so the percentage of 62% might in fact be much higher.

Data presented above include both cane molasses and beet molasses. The data for domestic use of molasses in The Netherlands, Czech Republic, Slovenia and Cyprus is not available. In fact, the shares of cane molasses and beet molasses consumed can be said clearly. It depends upon how much they are produced inside EU and how much they are imported from outside of EU. Most of the molasses are consumed by food industry and the remainder is used in animal feed *(Web 14)*.

2.6.4.4 Principles and by-products of molasses fermentation

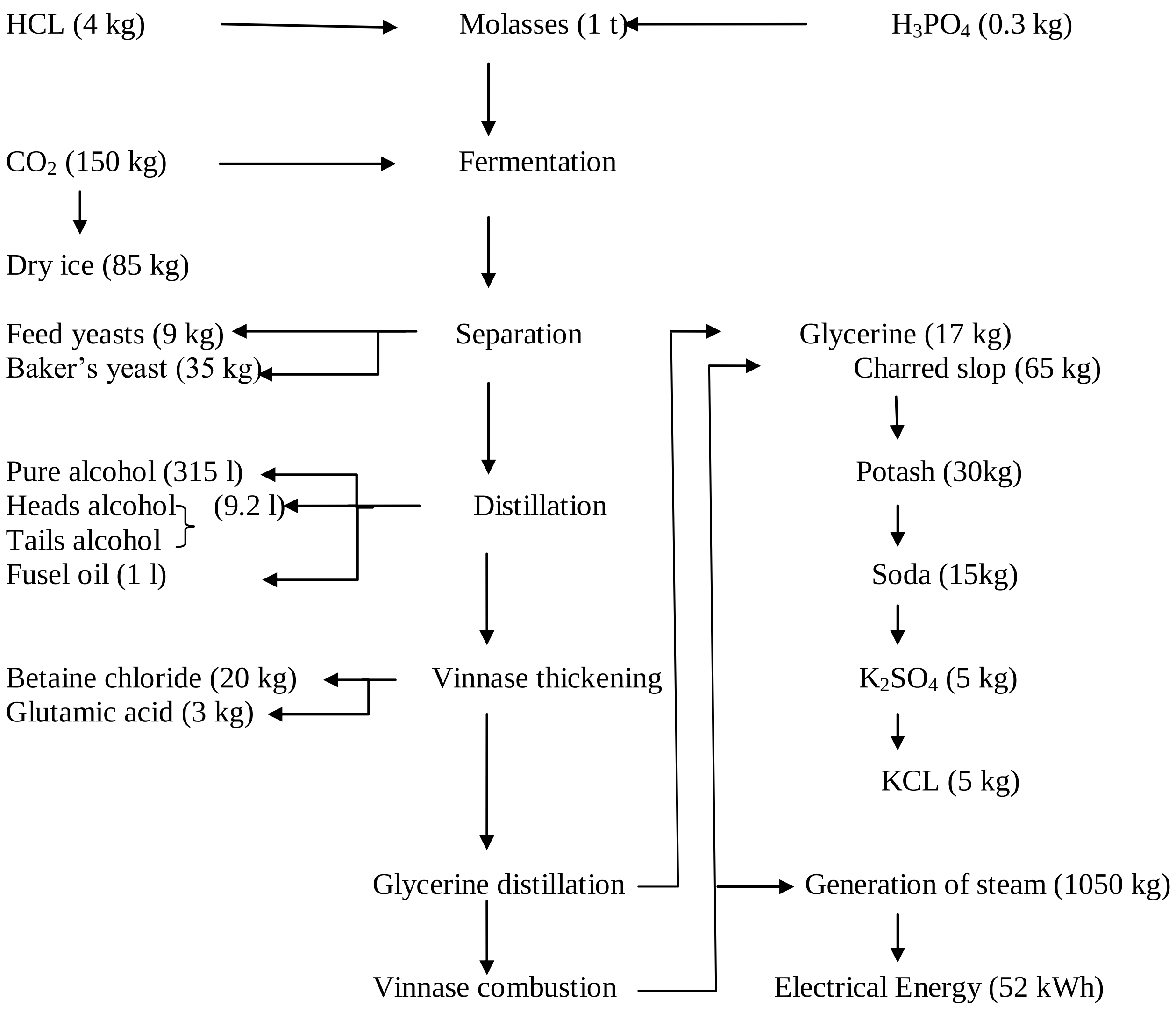


Fig 9: Flow chart showing principles and by-products of molasses fermentation

Source: Olbrich, 1963

2.7 Utilizations of by-products of sugar beet industry in different sectors

2.7a Industrial Sectors
2.7b Animal feeding
2.7c Agricultural Sectors
2.7d Human consumption

2.7a.1 Use of sugar beet pulp in production of paper and board

Beet pulps can be used in the production of paper and board. The inventors Wong and Bregola, (2010) carried out ensilage according to known methods with pulps preferably containing 15 to 35% of dry matter. According to them ensilage was lasted until the pH was at least less than about 5 and greater than about 3.5. During ensilage, lactic acid was produced in a quantity that varies as a function of the sugars available which concentration generally ranges between 1 and 10% of the DM of the beet pulps. The fermentation process was conducted under anaerobic conditions in the presence of lactic bacteria which are capable of converting the residual sucrose of the pressed beet pulps to lactic acid causing a fall in the pH and hence maintaining the structure of the beet pulps. The pulps were diluted to 1 to 10% of DM before moderate mechanical shearing. Shearing is necessary in order to obtain an adequate distribution of the dimensions of the fermented pulps. The optimum quantities of fermented pulps added depend on the type of paper or board which is produced and on their desired characteristics.

Depectinisation and dehydration of raw beet pulps can be another method used in paper production. The raw pulps penetrated with acidified water undergo various steps of compression and decompression. These compression and decompression produces a kind of steeping of the pulp fibres. The fibres separate from one another disappearing their directional arrangements. The pectins are dissolved resulting the final dried product suitable for paper production *(Wong and Bregola 2010).*

2.7a.2 Use of sugar beet pulp and sugar beet tail as fuel

Beet pulp can be fermented to produce fuel such as biogas or can be burnt directly as fuel. According to Otorowski (1990) in Cheesman (2004), it is necessary beet pulp should have more than 50 % moisture content for direct burning. The author also reports that burning the beet pulp directly can result in better heat efficiency than converting it to biogas by anaerobic fermentation, estimating dried pulp (90 % DM) generates half as much as heat as an equal weight of fuel oil in an efficient boiler. UNEP (1982) in Cheesman (2004) notes that there might be possibilities of obtaining alcohol from beet pulp by microbial fermentation which could be a good alternative if conducted using wet pulp at profitable level. SBT can be stored as silage for a long time and can serve as a continuous supply of biogas plants *(Kryvoruchko et. al., 2008).* According to Bukvic et. al., (2008) sugar beet leaves and heads that stays on plough-land during sugar beet root extraction presents great biomass potential and can be used for biogas production.

Table 11 Specific biogas and methane yield as well as energetic efficiency (η) of SBP silage and SBT

	Biogas yield [lN /kg VS]			Methane yield [lN /kg VS]			
Variant	Mean	n	S.D	Mean	n	S.D	Efficiency η
SBP	845^b	3	33.3	430^b	3	18.1	87.4
SBT	970^a	3	68.7	481^a	3	32.4	88.5

n = number of measurements, S.D. = standard deviation. Mean values within a column with different lower case letters are significantly different (P < 0,05; Tukey-HSD-Test).

Source: Kryvoruchko et. al., 2008

2.7a.3 Use of sugar beet pulp in preparation of activated carbon used as decolorizing agent

Activated carbons are generally produced from environmental wastes with high carbon content. It is used as material to clean environmental pollution like gases and liquid impurities. There are especially two methods to prepare activated carbons; physical and chemical activation.

Chemical activation method is used when the raw material is sugar beet pulp. SBP is impregnated with the activating agent $ZnCl_2$ in the ratio 1:1 to prepare impregnated sample. Then the sample is heated to activation temperature under N_2 flow (100 ml/min) at the rate of 10˚C /min and hold for 1 hour at the activation temperature. The activation temperature was varied over the temperature range of 400-900˚C. The sample is now cooled down under N_2 flow and HCl is added to the activated sample. After several washing of the sample with hot distilled water and finally drying it to 110˚C gives the activated carbons. These activated carbons seem to be essentially microporous *(Onal et. al., 2007).* Mudoga (2008) studied sugar syrup decolorization using two commercial and eight beet pulps based activated carbons. The author states that the two commercial activated carbons showed different decolorization efficiencies which could be related to their physical and chemical properties. According to the author the decolorization efficiency of beet pulp carbon prepared at 750˚C and activated for 5 h using CO, was much better than the others and close to the better one of the commercial activated carbons used. It shows that beet pulp is an inexpensive potential precursor for activated carbons for use in sugar refining.

2.7a.4 Use of sugar beet pulp in production of ethanol

In the present context that the majority of cellulosic ethanol studies have been focused on the use of feedstocks such as corn stover, wheat straw, switchgrass, or hybrid poplar wood chips, ethanol production from agricultural residues like sugar beet pulp can reduce the economic, political, and environmental impacts of petroleum use while strengthening rural economies. In comparison with sugar beets, these feedstocks may have greater potential for ethanol production on a national scale but beet pulp has potential economic advantages which have still to be explored fully. Other feedstocks need the expensive thermo chemical pretreatment which can be excluded in the case of SBP because of its unique composition. In addition, the resource is available at sugar processing plants and requires no additional harvest, storage, or transportation. It makes the ethanol production efficient and feasible in the regional level. According to the researchers, SBP is hydrolyzed to a complex mixture of sugars including glucose, arabinose, and galacturonic acid. This mixture of sugars is fermented to maximize ethanol yields and titters by using a recombinant bacterium, *E. coliKO11*, and conventional yeast, *Saccharomyces cerevisiae*. Pulp is hydrolyzed with conventional pectinase and cellulase enzymes and fermented sequentially with the two organisms or in parallel after partial hydrolysis. Maximizing solids loading rates will be a key factor in maximizing ethanol concentrations *(Pryor et. al., 2010).*

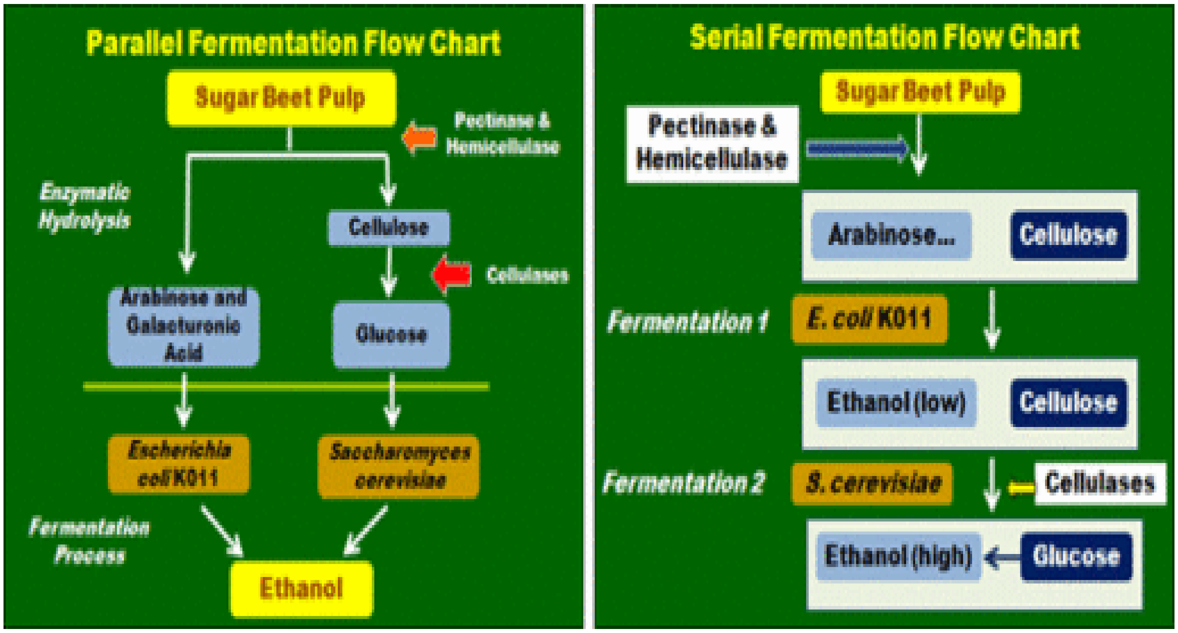


Fig 10: Flow chart showing fermentation of SBP

Source: Pryor et. al., 2010

2.7a.5 Production of alcohol from molasses

Molasses, the noncrystallizable residue remaining after sucrose purification, is accepted as the widely used raw material for the industrial production of ethanol. Its additional advantages over other materials are its easy availability and the cost i.e. it is relatively inexpensive with compared to other raw materials. It is recommended that the sugar content should be high when molasses is to be fermented to alcohol. Raffinose which amounts to 0.5 to 2% in beet molasses is broken down into fructose and melibiose by yeasts which contain the enzyme *saccharase* and melibiose is further broken into glucose and galactose by some yeast (e.g. bottom yeasts). Raffinose is broken down completely by bottom yeast, top yeast ferment only one third of the raffinose. If the operating conditions are good about 64 litres of alcohol are obtained from 100 kg of sugar processed molasses *(Olbrich, 1963).* The *Saccharomyces cerevisiae* is widely used as a biocatalyst in bioconversion processes and is suitable for production of ethanol from molasses under certain conditions *(Park and Baratti, 1991 in Ergun and Mutlu 2000).* Several studies exist in the literature concerning the effects of the sugar concentration, addition of different supplements to the molasses, pH, and some other factors on productivity, but in an independent variable form *(Ergun and Mutlu 2000).* Because of the digestible nitrogen and phosphate deficiency of sugar beet molasses, ammonium phosphate, ammonium dihydrogen phosphate and ammonium sulfate are usually added to the yeast production and fermentation medium for better productivity *(Schneider (1971) in Ergun and Mutlu 2000).* Industrial beet molasses worts for alcoholic fermentation are also good substrate for growth of bacteria especially lactic acid bacteria. This bacteria inhibits the specific growth rate of yeast and specific rate of alcohol production in different ways. The use of large inoculums of yeast decreases the inhibition process.

Different uses of ethanol

a) As a fuel

The largest single use of ethanol is as a motor fuel and fuel additive. Brazil has the largest national fuel ethanol industry. Nowadays the use of ethanol-petroleum blends is growing in the market. Ethanol can be added to petroleum at up to 20 % (v/v) without modifications to vehicles engine. Ethanol added to the petroleum should be anhydrous because water will separate out in the base of vehicles petrol tank in cold weather. Modified vehicles can run entirely on ethanol and in this case 95% of ethanol can be used. As a pure compound, ethanol has fixed boiling point, specific gravity, heat of vaporization and heat of combustion. Ethanol has high compression ratios; better ignition and high burning rate *(Hacking, 1987).* Ethanol offers high octane quality for spark-ignition (SI) applications and has other favorable attributes as an alternative transportation fuel. Ethanol may also be utilized as a rocket fuel. As a renewable energy source, ethanol is expected to significantly reduce carbon dioxide (CO_2) emissions when entire fuel cycle is considered *(Wyman, 1996).*

b) Alcoholic beverages

Ethanol has a principle role in production of alcoholic beverages. It is the principle constituent in alcoholic beverages that has depressant effect on central nervous system of the human body. It is also known to cause psychological addiction as well as chemical addiction. There are three general classes of alcoholic beverages; beer, wine and spirits. These are legally consumed in most of the countries and over 100 countries have law regulating their production, sale and consumption. The minimum ages of the people those can buy the alcoholic drinks varies from 16 to 25 but in general most of the countries has adopted it as 18 *(Web 15).*

c) Antiseptics

Ethanol is used as antiseptics because it shows an effective antimicrobial activity. Alcohols exhibit rapid broad-spectrum antimicrobial activity against vegetative bacteria (including mycobacteria), viruses, and fungi. But they cannot kill the spores. They are, however, to inhibit sporulation and spore germination, but this effect is reversible. Alcohols are not recommended for sterilization because of the lack of sporicidal activity, but are widely used for both hard-surface disinfection and skin antisepsis. Lower concentrations may also be used as preservatives and to potentiate the activity of other biocides. Ethanol kills organisms by denaturing their proteins and dissolving their lipids *(McDonnell and Russell 1999).*

d) Other uses

Ethanol can be mixed with water and can serve a good general purpose solvent. Its uses include paints, tinctures, markers, and personal care products such as perfumes and deodorants. It can also be used as a solvent in cooking, such as in vodka sauce. Before the development of modern medicines, ethanol was used for a variety of medical purposes. It has been known to be used as a truth drug as medicine for depression and as an anesthetic *(Web 16).*

2.7a.6 Production of glycerol from molasses

Glycerol (or glycerin, glycerine) is a colorless, odorless, viscous liquid that is widely used in making medicinal product. It is soluble in water and hygroscopic in nature. Glycerol is sweet in taste and of low toxicity. It is a by-product of fermentation process. Glycerol is a widely used chemical in many commercial applications. We can find its largest use in the manufacture of drugs and oral care products including toothpaste, mouthwash and oral rinses. Glycerol is also used in foods and cosmetics, tobacco, wrapping and packaging materials, lubricants, urethane polymers, gaskets, cork products, cement compounds, soldering compounds, compasses, cleaning materials, detergents, wetting agents, emulsifiers, skin protectives, asphalt, ceramics, photographic products, leather and wood treatment and adhesives *(Morrison (1994) in Taherzadeh et. al., 2002).* Glycerol can be produced by fermentation process. The glycerol formation accompanying ethanol production in fermentation dates back early the investigations of Pasteur 1858. At that time, a process was established based on research conducted by Neuberg *(Neuberg and Reinfurth, 1917 and 1919).* The processes were not so effective in competition with processes adopted for synthetic glycerol production because of some drawbacks of fermentive process like low yield of glycerol from carbohydrates and difficulties in the recovery of glycerol from the fermentation broth.

While using the yeast *Saccharomyces cerevisiae*, glycerol is a by-product of the fermentation of sugar to ethanol in a redox-neutral process. Van Dijken and Scheffers 1986 in Prior et. al., 2001 notes that the role of NADH-consuming glycerol formation is to maintain the cytosolic redox balance especially under anaerobic conditions, compensating for cellular reactions that produce NADH. Substantial overproduction of glycerol from monosaccharide can be obtained by yeast:

a) Forming a complex of acetaldehyde with the bisulfite ion that limits ethanol production and that promotes reoxidation of glycolytically formed NADH by glycerol synthesis
b) Growing at pH values around 7 or above; and
c) By using osmotolerant yeasts *(Rehm, 1988; Agarwal, 1990 in Prior et. al., 2001).*

The first method, based on the trapping of acetaldehyde by bisulfite ions, yields the reaction:

$$Hexose+bisulfite \rightarrow acetaldehyde\text{-}bisulfite+CO_2+H_2O+glycerol$$

Acetaldehyde is unable to serve as an electron acceptor for cytosolic NADH and the accumulated NADH is instead oxidized by the reduction of dihydroxyacetone phosphate to glycerol-3-phosphate. The second method operated at pH values of 7 or above, is based on the reaction with stoichiometry:

$$2hexose \rightarrow 2glycerol+ethanol+acetic\ acid+2CO_2+2H_2O$$

This reaction occurs in parallel with the normal alcoholic fermentation *(Neuberg and Hirsch, (1919) in Prior et. al., 2001).*

2.7a.7 Production of rum from molasses

Manufacture of rum is typically and traditionally indigenous to the cane sugar regions. Raw material for production of rum is mainly the cane molasses and the product from the processing of cane sugar. But molasses from beet sugar processing is also used as a raw material for production of rum. In production of rum, *Schizosaccharomyces* strains are used for the heavy aroma rums and *saccharomyces* which has character of quick fermentation are used for lighter rums. Bacterium *Clostridium saccharobutyricum* can be used for accelerating the formation of alcohol during fermentation by yeast. During fermentation, a number of constituents called congeners are also manufactured. These congeners i.e. aldehyde, acids, fusel oil, Easters etc which are regarded as the rum flavours, are the major constituents of the heavy type rums. These congeners are necessary for blending to give the flavour and character to rum. According to Trehan (1990), the best yield of rum can be achieved if the ratio of bacteria to yeast is 1: 5. The bacteria are added when the ethanol concentration is 3.5-4.5% and the sugar content is 6% (w/v). The final distilled product is aged in the wood (oak) barrels for several years which contribute to the flavour of the rum too.

2.7a.8 Manufacture of yeast from molasses

Molasses is the main raw material in production of yeast in commercial level. Both cane molasses and beet molasses can be used but some yeast manufacturers use mixture of both cane and beet molasses. Molasses should be clarified and sterilized with high pressure steam before feeding to yeast cells to prevent bacteria and other organisms from being introduced *(Web 17).* It also helps to ensure the final color of the yeast. The molasses is then diluted with water and heated to boiling point. The ph value is adjusted to between 4.5 and 5 because an alkaline mixture promotes bacteria growth. The initial stage of production of yeast is growing the yeast from the pure culture in series of fermentation vessels. Yeast cell vessels should be operated in aerobic conditions in case the fermentable sugars are consumed in formation of ethanol and carbon dioxide in anaerobic conditions which results in low yield of yeast. The yeast strain used to in producing compressed (cream) yeast is *Saccharomyces cerevisiae.* Compressed yeast and dry yeast are produced in similar manner but dry yeast are developed from different yeast strain and dried after processing. Two types of dry yeast exist, ADY and IDY. Production of yeast requires varieties of nutrients (nitrogen, potassium, phosphate, magnesium and calcium with traces of iron, zinc, copper, manganese and molybdenum) and vitamins (biotin, inositol, thiamine and pantothenic acid). Compressed yeasts are mostly consumed by wholesale bakeries and dry yeasts are mainly consumed for home baking needs *(Web 18)*.

2.7a.9 Production of citric acid from molasses

Despite of several processes used in production of citric acid, it is produced commercially by submerged fermentation of cane and beet molasses. Beet molasses is used widely in Europe and North America for production of citric acid. Successful utilization of it in fermentation by molds is highly desirable. Fermentation by *Aspergillus Niger* (mold) under surface and submerged conditions continues to be a predominant process since its invention to till the present time. According to Rehm et. al., (1983) in Bielecki et. al., (2000), there is certain favourable conditions to be met to increase the rate of production of citric acid like high sugar concentrations, low pH, low concentration of phosphate, absence of trace metals and high concentration of oxygen.

Bielecki et. al., (2000) notes that excess of nutrients and microelements in the molasses promotes biomass development instead of citric acid accumulation which can be maintained by addition of potassium ferrocyanide. It reduces the content of available heavy metals that causes unfavourable conditions for citric acid biosynthesis. Besides citric acid, the fermented liquid contains several unwanted materials including oxalic acid and residual sugars. There has to go several processes like precipitation, ion exchange and solvent extraction in recovery of citric acid from fermented liquor. Citric acid is used in food processing, pharmaceuticals and industrial usage like plasticizers in plastic industry, detergents, metal cleaning, textile printing and dyeing, photography and others *(Web 19)*

2.7a.10 Production of butanol and acetone from molasses

These are the organic solvents produced by clostridial fermentation of a range of raw materials including molasses. Early in the 20th century, Weizmann from UK conducted much of the basic researches in the production of acetone, butanol and ethanol by fermentation using *Clostridium acetobutylicm*. The use of acetone in manufacturing of explosives during World War I made its production valuable. Following World War I, production of butanol attracted the mind of manufacturers which was used extensively used as feed stock chemicals in the production of lacquers, rayon, plasticizers, coatings etc for synthetic rubber manufacture. Butanol was also utilized as a solvent for fats, waxes, resins and as an extractant and solvent in the food industry. Butanol can be used as motor fuel or can be blended with gasoline. According to Waites et. al., (2001) butanol has characteristics like good octane enhancing properties, relatively high heat of combustion and much lower vapour pressure than both methanol and ethanol those makes it even better liquid fuel extender than ethanol which is currently used in the formulation of gasohol.

2.7a.11 Production of glutamic acid and betaine from molasses

Nowadays most of the sugar industry has its own distilleries attached within it to utilize the by-products of the sugar industry. Especially molasses when is used to produce alcohol by fermentation results vinasse as a residue after distillation process. Decloux et. al., 2000 notes that for each litre of ethanol production, 10-15 litres of vinasse is evacuated from distillery units. According to Kampen and Saska, (1999) in Decloux et. al., (2000) vinasse of sugar beet molasses is rich in glycerol (6g/l) and betaine (15-20g/l). In study conducted by SNPAA in 1994 noted in Decloux et. al.,(2000) the nitrogen content in vinasse is almost totally in organic form i.e. amino acids, glumatic acid salts and betaine (2-4%). As stated in Olbrich (1963), the glutamic acid is made from the pyrrolidone carboxylic acid by hydrolysis. Amelung (1953) in Olbrich (1963) noted that there are several ways of obtaining betaine vinasse of sugar beet molasses. One of them can be treating the thick vinasse with equal parts of ethyl or methyl alcohol and heating. The alcohol extract contains up to 50% betaine in the DS and after distillating the alcohol the betaine in its hydrochloride form can be obtained. But the use of ion exchange technology is the simple which retains betaine and inorganic cations present in vinasse or molasses.

2.7a.12 Generation of electricity from vinasse of molasses

Vinasse, the liquid residue obtained after the distillation of alcohol, can be used in the production of biogas which eventually can be utilized in the generation of electricity. According to the Ethanol Producer Magazine, (2006) the biogas that is not converted into electricity can be scrubbed to pipeline specifications natural gas, compressed and injected into the existing natural gas distribution grid. Thus the distribution lines are used as the storage system. Vinasse represents an enormous volume of wastewater for disposal which should be handled with proper management as it is an economical and environmental concern. The restrictions for effluents BOD discharge by current environmental laws and regulations stimulates the industries to adapt the anaerobic digestion of vinasse to reduce BOD in wastewater treatment since gas of high caloric value can be obtained as well as relatively inoffensive sludge suitable for use as a fertilizer. The vinasse is first introduced into the reactor (digester) where anaerobic bacterial culture that carries out the conversion of organic material to various end products including methane (CH_4), carbon dioxide (CO_2), ammonia (NH_3) and cell or bacterial mass is maintained. The mixture of gas is collected in the dome of the reactor as methane is highly insoluble in water and further the gases are withdrawn for energy recovery. The gases are used to rotate the turbines and hence generate the electricity. The turbine exhaust gases can generate steam that can be utilized in other sections of the industry that requires energy. The digested vinasse can be evaporated to 65% solids and can be utilized by burning it to create additional energy. When the vinasse BOD ranged from 17000 to 50000 mg/l is processed, 3.6 to 10.6 megawatt of electricity can be produced assuming that the thermal efficiency is 90% *(Baez, 2006).*

2.7b Animal feeding

2.7b.1 Use of sugar beet pulp in animal feed

Harland (1993) in Cheesman (2004) notes that, after extraction of sucrose from the processed beet slices, wet pulp is produced with a dry matter content of just 6-12%. It can be consumed directly as a animal feed or can be pressed first to increase the dry matter content up to 18 -30 %. Pressed pulp can be ensiled, further dried to increase the dry matter content to 87-92%, mixed with molasses or can be mixed with molasses first and then dried. Beet pulp provides livestock with energy (which are mostly derived from structural carbohydrates) and digestible fibre. It is suitable for feeding to the ruminants and more sparingly to pigs. Digestibility of feed can be increased using it with other feeds (such as those based on straw and hay) making it valuable addition to livestock rations. Pressed pulp is widely used throughout Europe as animal feed. It should be used within 5-7 days, if mould growth and spoilage are to be avoided, or ensiled *(Kunteova, 1997)* with appropriate care, to maximize the quality and quantity of silage recovered. Dried plain sugar beet pulp has relatively low water content and is relatively stable and can (generally in pellet form) be used for feed directly or stored for up to a year. De Brabander and Boucque (1992) in Cheesman (2004) notes that use of feeds like sugar beet pulp can help to reduce the environmental impacts associated with livestock farming by reducing nitrogen excretion and total faecal dry matter production by cattle when compared with grass-based feeds.

a) Dairy cows

It is generally assumed that the effect of dry matter intakes either in the form of pressed pulp or dried pulp behaves similar when fed to livestock. In one of the few comparative trials that have been carried out by Hemingway (1986), dairy cow performance was not affected when 5 kg/day DM (dry matter) was fed in either form, but protein degradability differed greatly at 0.07 and 0.60 for dried and pressed pulp respectively. Pulp protein availability in the rumen seemed to be significantly altered by the drying, although it was unclear whether this was of practical significance. According to De Visser and Tamminga (1987) in Draycott (2006), there is no any significant difference on milk production or composition with respect to the forms of feed fed to the cattle. Cows fed with pressed pulp had lower DM intakes in early lactation and therefore were in a more negative energy balance initially and lost more weight. 25% of the DM intake of dairy cows feed can be sugar beet pulp *(Steg et al., (1985) in Draycott, 2006)*, which can also increase the energy density of rations, particularly those based on poorer quality forage.

b) Beef cattle

A supplement of protein and mineral/vitamin mix is generally required in the diet. Besides these constituents in the diet, sugar beet pulp may comprise the major proportion of the diet. Harland (1981) in Draycott (2006) notes that when finishing beef cattle were fed on up to 40 kg/day pressed pulp, equivalent to 10 kg/day DM and representing over 80% of the total DM intake, they grew well, with liveweight gains of 1.2-1.5 kg/head/day. Pressed pulp was palatable enough to calves from the age of 3 months and also well accepted by all animals, and had no adverse effect on growth or efficiency of liveweight gain *(Nuttall, (1981) in Draycott 2006).*

c) Sheep

Sugar beet pulp can be utilized by growing and fattening lambs in large proportion in their diet. Theiez and Brun (1983) in Draycott (2006) reports that there is no any significant changes in liveweight gain when up to 81% cereal of a lamb fattening diet was replaced by dried beet pulp, however the carcass quality tended to improve. Lambs fed with dried beet pulp pellets gained faster and more efficiently in comparison with lambs fed with an equivalent amount of DM from pressed or wet pulp. Stern and Metwally (1990) in Draycott (2006) notes that lambs those are fed with more beet pulp (33% of dietary DM) gained faster but not more efficiently than lambs fed with less beet pulp (15% of dietary DM).

d) Pigs

Sugar beet pulp has been utilized as one of the constituents in the growing pig diets. Longland et. al., 1993 in Draycott (2006) suggested that a period of 3-5 weeks was required for maximal digestion to takes place. An additional benefit identified by Longland et. al., (1991), was the quality of pork for human consumption has superior properties if they are fed with the SBP. Kreuzer et. al., (2002) in Draycott (2006) also demonstrated that the cholesterol levels were lower in blood and muscle from pigs fed SBP and suggested that the pork from these animals could be beneficial to human health. Additional benefits from including SBP in sow diets include increased food intake during lactation, higher piglets weights at birth, faster growth of piglets and improved satiety of sows during pregnancy when feeding is restricted *(Edwards et al., 1989; Close et al., 1990 in Draycott, 2006).*

e) Horses and ponies

The wet sugar beet pulp could be used for horse feeding by ensiling the wet beet pulp but it is rarely used in this way. Most beet pulp is dried and sold in a market as dried SBP, or mixed with 10% molasses to form molassed SBP, which provides sugar, pectin and betaine, and sold normally in a form of cube. The dry cubes should not be given to horses on directly without soaking because in the dry form they can cause choke in some animals. In case dried beet pulp constitutes a high proportion of the concentrate mix then large quantities of free fluid are absorbed by the mass in the stomach and colic can result. The carbohydrate it contains is rich in pectin, but also contains cellulose and hemicelluloses which are fermented by the large intestinal flora of the horse. The dried form mixed with other feeds is used successfully in coarse mixtures and large quantities, soaked, act as a useful cereal replacer in laminitis control. It has a uniform composition and is free from toxins. The protein content and qualities are similar to those of cereals. Urea is sometimes added to beet pulp. It is with no value to horses, but causes no harm in those with fully functioning kidneys *(Frape, 2010).*

f) Sugar beet-top in the diet of lactating buffalo

Although the sugar beet tops are not accounted as the by-products of sugar beet industry as they are left in the field during harvesting, they can be utilised in various ways. Sugar beet tops are harvested and chopped into 3-6 cm then mixed with sugar cane bagasse and sugar cane molasses to provide a mixture contained 30-35% DM, then it was ensiled in common silo. Then after two months the ensiled mixture is fed to the lactating buffalo with the controlled diet. According to Fazaeli et. al., (2010) the high milk yield is obtained when the lactating buffalo is fed with the controlled diet mixed with 50% silage. The silage obtained can be used as a roughage portion of the diet in milking buffalo as it provides more nutrients to improve milk performance.

2.7c Agricultural sectors

2.7c.1 Uses of CLR (lime cake)

CLR is rich in calcium carbonate content and also contains other substances like nitrogen and minerals that can be utilized in agricultural sector. CLR can be used as soil enhancer and also as soil pH adjuster. As it is cheaper in comparison with other fertilizers, it is more economical for farmers. It not only limes the soil but also provides other minerals that give extra value to soil *(Asadi, 2007).* It can be recycled into the prelimer in the beet factory. In the present context, desulphurization of fuel gases is essential from the environmental point of view and can be achieved by the use of carbonation mud *(Dolignier and Martin (1997) in Sarka et. al., 2007).*

2.7d Human consumption

2.7d.1. Uses of sugar beet pulp as ingredients of human food

SBP has been used as a palatable, fibrous food ingredient for human consumption. The inclusion of sugar beet fibre in diet of healthy volunteers has resulted in positive effects in the human health. It helps to reduce the levels of both postprandial plasma glucose and blood cholesterol *(Morgan et. al., (1988) in Draycott, 2006).* SBP can be used as a source of hydrocolloids to improve bread quality. Its presence causes several changes to dough and bread properties like water consumption, degree of softening etc. SBP can increase the dough consistency and therefore is suitable to use along with weak flours. Bread made with SBP had lower density, softer texture and later staling compared to ordinary breads. SBP should be used at levels less than 5% to avoid changes in bread color, taste and flavor or it should be bleached before being used in bread formulations *(Williams and Phillips 2009).*

2.8 Overview of sugar campaign 2010/11 in the Czech Republic

During the campaign 2010/11, the average sugar content was 16.65 %. A total of 2.919 million tons of sugar beet was processed which were harvested from 49.25 thousand ha with an average yield of 59.27 t/ha of sugar beet and 9.87 t/ha of polarisation sugar. The total processing time of sugar beet was 93.3 days and the total production of white sugar from the beet was 432.75 kilo tons. Besides white sugar, 88.5 thousand tons of molasses were produced. Agroethanol is also produced in *Sugar Company and distilleries TTD, Dobrovice (Web 20).*

III. Objective of the thesis

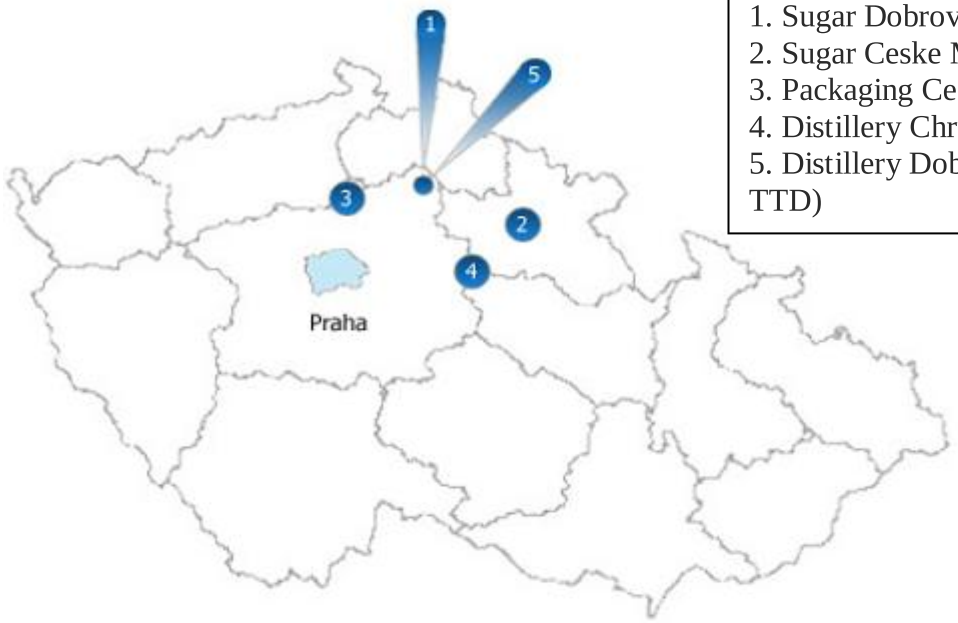
The objective of the thesis is to observe the by-products and the processing of sugar beet industry. In my analysis, regarding by-products of sugar beet industry, it is limited to pulp and lime cake residue. Unfortunately it is not possible to make analysis of molasses in factory where I did my entire analysis however it is the most important by product of sugar beet industry and is described theoretically in my work.

IV. Materials and Methods

4.1 Characteristics of the sugar beet processing plant

Sugar Dobrovice is one of the five branches of the *Sugar Company and distilleries TTD* which history dates back to 1831. It is situated in Dobrovice, Czech Republic and currently the largest Czech producer of sugar and alcohol (fine, technical, and bio-ethanol). Bio-ethanol plant in Dobrovice, which is operated by a subsidiary of Agroethanol TTD, is the first industrial distillery for the production of anhydrous alcohol fermentation (bio-ethanol) in the Czech Republic. Production of bio-ethanol was launched in October 2006. Initially the processing capacity of *Sugar Dobrovice* was 1000 tons of beet day, which to date has risen to 14,000 tons of beet per day. The campaign in the *sugar Dobrovice* generally begins each autumn and lasts about 90-100 days, producing 140,000 tons of sugar. Processed beets in *Sugar Company and distilleries TTD* come from of 410 independent growers and are growing at more 30,000 hectares in different parts of Czech Republic. Currently 350 employees are working in this company. Besides sugar and alcohol, the company also produces 75000 tons of pellets annually.

Sugar Dobrovice treated 14025 tons of sugar beet on the 59th day of the campaign 2010/11 which has sugar content of 17.71% and produced 1540 tons of white sugar to storage. It produced 525 tons of dry pellets and 528 tons of molasses with 51.4 % polarisation on that particular day of campaign. It uses various chemicals for daily performance of the factory. For a season, they use 600 g of sodium hydroxide (NaOH) for per ton of sugar beet processed, similarly 150g of formalin, 25g of suphur, 900g of sulphuric acid (H_2SO_4), resins, 10-15 ppm of biocides for each ton of beet processed. On the 59th day of the campaign, they produced 358.67 thousand m^3 of gas from wastewater treatment and bought 364.32 thousand m^3 of gas. They produced 267.2 Mwh of energy and 1.9 Mwh part of which they sold to others. They use this energy in different stations of the factory. For drying of pellets they used 27.3 Mwh of energy on that particular day of the campaign.



1. Sugar Dobrovice
2. Sugar Ceske Mezirici
3. Packaging Centre Melnik
4. Distillery Chrudim
5. Distillery Dobrovice (Agroethanol TTD)

Fig 11: Location of Sugar Company and Distilleries TTD

Source: <http://www.cukrovaryttd.cz/o-spolecnosti/rozmisteni-zavodu/>

4.2 The laboratory methods used

All the tests were performed in the laboratory of *Sugar Dobrovice*, Czech Republic. The samples were taken from the respective sample taking points of the sugar factory in different intervals of time. The duration of the tests was five days i.e. from 15th of November to 19th of November 2010. The methods mentioned below are given by the norms ČSN 56 0160:

CSN 56 0160-3 Determination of dry matter

CSN 56 0160-4 Determination oh pH

CSN 56 0160-5 Determination of sucrose polarization

CSN 56 0160-6 Determination of ash

CSN 56 0160-8 Determination of color

CSN 56 0160-9 Determination method for granulometric composition

All the methods I mentioned here except for color are abstracted from the book "*Laboratorni Kontrola Cukrovarnicke Vyroby"* by Friml and Ticha (1977)

4.2.1 Determination of polarisation (Pol %)

The polarization measurement was performed with a digital polarimeter having tubes 200 mm in length and automatic temperature compensation. The following things were also used:

Analytical balance with an accuracy of ± 0.001 g
Erlenmeyer flask 200 ml
Filter paper
Filter funnel and beaker
Distilled water
Clarifying agent those are ether, $Pb(CH_3COO)_2$ (lead acetate) and $ZnCl_2$ (zinc chloride)

The room temperature should be maintained standard i.e. 20˚C and only distilled water should be used for making solutions.

a) Polarisation of diffusion water, press water and milk of lime

First the sample was cooled to standard temperature. 52 g of the sample was weighed in the analytical balance and transferred into a 200 ml Erlenmeyer flask by washing with distilled water. Then 5-20 ml of lead acetate was added to the sample and swirled. Distilled water was added to the sample. If there is foam creation then ether can be used to clear it. The mixture then was stirred by shaking. It was filtered in the beaker using funnel filter. Polarimeter tube was rinsed with the clear sample twice and then it was filled and placed in the polarimeter. The value displayed in the screen of polarimeter is the value we wanted. But in case of diffusion water and milk of lime the value displayed in the screen should be multiplied by 0.26 to obtain the polarisation.

b) Polarisation of diffusion juice, thin juice and thick juice

The process was similar to process of diffusion water, press water and milk of lime but the value of polarisation is the value displayed in the device.

c) Polarisation of cossettes, wet pulp, pressed pulp and pellets

First 23.14 g of cossettes were taken after grinding the sample in the grinder. It was mixed with 356 ml of lead acetate and warm water at 80-85˚C. It was left for half an hour and let it to be cool to 20˚C.Then the sample was filtered in the beaker using funnel filter. Polarimeter tube was rinsed with the clear sample twice and then it was filled and placed in the polarimeter. The value displayed in the screen of polarimeter should be multiplied by 2 to obtain the value of polarisation of cossettes, wet pulp and pressed pulp where it should be multiplied by 4 in case of pellets.

d) Polarisation of the sludge

First 40 g of sludge sample were taken and it was mixed with 100 ml of zinc chloride. It was left for few minutes. Then the sample was filtered in the beaker using funnel filter. Polarimeter tube was rinsed with the clear sample twice and then it was filled and placed in the polarimeter. The value displayed in the screen of polarimeter the value of polarisation.

e) Polarisation of syrups, sugar A, sugar B and sugar C

First 100 ml of sample and 100 ml of distilled water were mixed for dilution. Then 52 g of the mixture was weighed and transferred into a 200 ml flask. The further processes were same as mentioned before for diffusion water, press water and milk of lime. The final value displayed in the screen of polarimeter should be multiplied by 2 to obtain the exact polarisation.

4.2.2 Determination of draft

The draft was calculated using following formula

$$\textbf{\textit{Draft}} = \frac{Pr - 0.225\,Z}{Pd} * 100\ \%$$

Where,

Pr is sugar content in cossettes

Z is sugar content in pressed pulp

Pd is sugar content in diffusion

4.2.3 Determination of DS (°Bx)

The digital refractometer with automatic temperature compensation was used to measure quantity of DS present in the sample. To determine DS of diffusion water, diffusion juice, diffusion juice for distillery, slices, pellets and thin juice small amount of sample was put on the glass facet of the device and the stable reading of the device is the value of DS content in the sample. For syrups and thick juice, the sample was first diluted in the ratio 1:1 and the obtained value was multiplied by 2 to get the DS content in the sample. The glass facet of the device should be wiped properly for each consecutive test. Before the measurements the glass facet of the device must be dry and clean. The instrument is calibrated once a day to zero with distilled water.

4.2.4 Determination of pH

To determine pH value, digital pH meter was used. The electrode of the device was introduced with the sample and the reading was taken. It is necessary to rinse the electrode twice for each different test. For syrups and thick juice, the sample can be first diluted with distilled water.

4.2.5 Purity

Purity of the sample was found by using formula

$$\boldsymbol{Q = \frac{S}{DS} * 100}\ \%$$

Where,

Q is the purity of the sample
S is the sugar content of the sample and
DS is the dry substance in the sample

4.2.6 Determination of lactic acid in the sample

Enzymatic method was used to determine the lactic acid in the sample. The enzyme biosensor based on amperometric detection was the device used and the enzyme was *lactate dehydrogenase*. The principle of measurement is based on the enzymatic reaction in electrochemical reactions. Put few drops of sample were introduced to the device and the reading was taken which is the value we were seeking for.

4.2.7 Alkalinity test

First the sample was filtered. 28 ml of sample was taken in the titration flask. Then we added few drops of phenolphthalein indicator and titrated the sample with titrant 1N HCl solution unless the pink color disappeared. Concentration of 1N of HCl solution was used for pre limed and main limed samples and concentration of 0.1N of HCl solution was used for first and second carbonation samples.

The alkalinity was calculated as follows:

$$\text{Alkalinity} = \text{ml of titrant} * 0.01\ \text{gCaO/100ml of the sample}$$

Or,

$$\text{Alkalinity} = \text{ml of titrant} * 0.1\ \text{gCaO/l of the sample}$$

4.2.8 Hardness test

The method used was complexometric titration. The sample was filtered first. The sample was introduced to refractometer to determine the DS content. And then 100 ml of the sample was taken in the titration flask. The indicator used was Eriochrome black T .The sample was titrated with titrant Ethylenediaminetetraacetic acid (EDTA) until the blue end point reached.

The hardness is given by the following formula:

$$Hardness = \frac{ml\ of\ titrant}{ml\ of sample} * 100\ mgCaO/100ml$$

Or,

$$Hardness = \frac{ml\ of\ titrant}{ml\ of\ sample * density * DS} * 10000\ mgCaO/100DS$$

4.2.9 Color determination of the thin juice, thick juice, syrups and sugar

The sample of sugar solution was prepared mixing 100g sugar and 100 ml distilled water. It was introduced to refractometer to know the DS of sample. The clean and dry color tube was filled with the sample. The spectrophotometer was set to 420nm. The color is calculated using the given formula:

$$\text{ICUMSA Units (I.U)} = 1000* \quad \frac{100 * E_{420}}{l * DS * d}$$

Where,

E_{420} is the absorbance of the solution
l is the sample tube diameter
DS is the dry substance and
d is the density (specific weight of the solution)

4.2.10 Determination of turbidity

At first the color was measured in the unfiltered solution. Then its color was compared with color of the filtered solution. The difference between them gives the turbidity of the solution.

4.2.11 Determination of density

Hydrometer was used to measure the density of the sample especially here for density of milk of lime. The scale presented here is in ˚Baume or ˚Be.

4.2.12 Distribution of sugar crystal sizes

Multiple screen method was used to determine the sugar crystal sizes. Bench top sieve shaker was the instrument used in this case. The bottom pan and the screens were weighed and the mass were recorded. The bottom pan and screens were kept in the bench top sieve seeker allowing the bottom pan in bottom and screens with largest openings in the top and the smallest in the bottom. Then 100 gm of sugar was poured in the screens and shaking was introduced. After couple of minutes the screens were removed and weighed keeping the records. The percentage remaining on each screen was calculated by deducting the second weight (the weight of the screen and the sugar) from the first weight (the weight of empty screen). The special software in the laboratory was used to determine the coefficient of variation in the crystals with the help of the values obtained from the above screen test.

4.2.13 Color determination of the sugar crystals

The sample of sugar was taken and introduced to the instrument called saccharoflex for color determination of the sugar crystals. The number displayed in the device gives the value of color in sugar crystals.

4.2.14 Determination of ash content in sugar

Measurements should be carried out at 20˚C with a tolerance of 0.2˚C max. 31.3 g of sugar was taken and distilled water was put to make the weight to be 100 g. The solution was stirred using magnet. First only distilled water was placed in the measuring chamber of the conductivity meter and the reading was taken. Then the sugar solution was placed and the reading was taken. The ash content is given by the formula below.

$$X = 0.600*C\ (G-0.5G_w)$$

Where,

X = conductometric ash content in %

C = constant

G = conductivity of sugar solution in microseconds (µS)

G_w = conductivity of water in microseconds (µS)

4.2.15 Determination of moisture of the sugar

First a clean, dry stainless-steel moisture dish (with cover removed) was kept in the oven. After 30 minutes it was removed from oven and dish with its cover was placed in desiccators to cool to room temperature. The dish with its cover was weighed to the nearest 0.0001 g (W_1). About 10.0 g of sample was put into the weighed dish and again weighed together the dish plus the sugar (W_2). The dish and cover (remove the cover) were placed in the drying oven at 105ºC for 1 hour (or until constant weight is achieved). The dish and cover were removed from the oven, placed in the desiccators for 10 minutes to cool down, and then was weighed to the nearest 0.0001 (W_3).The moisture content is given by the formula stated.

$$\%\ Moisture = \frac{W2-W3}{W2-W1} * 100$$

4.2.16 Determination of water loss from pellets during drying

The method is more or less same as determination of moisture in sugar. 100 g of pellets were taken in the dish and weighed. Then it was kept in the dry machine at104˚C for 3-4 hours. The dish was removed from the dry machine and let it to cool down and was weighed again. It gives the dry mass of pellets and also we can find the water loss during drying comparing with the formula given above for moisture of sugar.

The ash content of pellets can be determined by putting 2 gm of pellet in the porcelain cup and keeping it in the oven at 600˚C for few hours. The remaining residue is the ash content in the pellets.

4.2.17 European points for sugar quality analysis

White sugar quality was defined nearly 40 years ago by European legislation in terms of points ("European Points") specified by the EU sugar market regime. According to legislation 1265/69 of 1 July 1969, the criteria adopted in order to determine points for white sugar quality are color type of sugar as compared to standards established by the Braunschweig Sugar Institute, color in solution (50% sucrose content) and conductivity ash. To satisfy the customer quality demand other complementary analyses such as polarimetric sugar, invert sugar, water content, grain size distribution, microbiology of sugar and turbidity are should be carried out in beet sugar industry *(Roge et. al., 2007).*

Properties of sugar or white sugar

Purified and crystallised sucrose of sound and fair marketable quality should have the following characteristics:

(a) Polarisation not less than 99.7 Pol %
(b) Invert sugar content not more than 0.04 % by weight
(c) Loss on drying not more than 0.06 % by weight
(d) Type of colour not more than nine points (European points)

The total number of points for white sugar should not exceed eight, and not more than:

- Four for the colour type,
- Six for the ash content,
- Three for the colour in solution.

The points refer to 0.5 units in the case of color, 0.0018% in the case of ash content determined by ICUMSA method and 7.5 units in the case of color in the solution (*Web 21)*

V. Results and Discussions

5.1 Assessment of raw material for processing plant

To obtain high sugar yield per unit area, besides achieving high yield of sugar beet roots, very important property is its technological quality. Except natural factors obviously which has impacts on the yield, there are others parameters on which sugar beet yield depends on regarding mistakes and omissions in technology of growing *(Marinkovic et. al., 2010).* Growers should know that little can be done to modify soil type; cultivations can alter only the structure of the given soil but should aim to optimise structure both in the seed-bed and lower in the soil profile *(Draycott, 2006 in King and May 2007).* Optimal structure will ensure the good, even plant population that must be achieved for maximum yield. The study conducted in 2002-2006 by Šařec P., Šařec O., Srb K and Dobek T concluded that economic efficiency of production of sugar beet in the case of simplified technology increased to an average of 2.44 and ranged from a 1.58 in 2002/03 to 3.67 in 2003/04, while in the case of traditional technology of soil preparation the average value of economic efficiency was 2.13 and ranged from 1.68 in 2002/03 to 3.12 in 2003/04 *(Šařec et. al., 2009).* Proper dosage of fertilisers plays significant role in resulting better quality and increased yield of sugar. The amount and ratio of applied nitrogen phosphorus and potassium mainly depends on soil fertility, plant characteristics and the desired yield and quality *(Saric, 1977 in Marinkovic et. al., 2010).* Among of all mineral nutrients nitrogen has the greatest impact on the yield and qualitative traits of sugar beet. Technological quality in beet roots is determined by the digestion and content of non sugar matters. Higher content of non sugar matter like organic nitrogen compounds in particular α-amino nitrogen, betaine and other organic bases as well as minerals like K, Na, Ca, Mg etc causes increase of sugar content in molasses reducing the efficiency of the production of refined sugar *(Karadzic et. al., 1990 in Marinkovic et. al., 2010).* It was found that the highest refined sugar yield (8.25%) was obtained when the dosage of the NPK fertilizers was 2:1:1. Many authors have pointed out that the dosage of NPK over 100kg/ha almost regularly lead to reduction of sugar content in beet *(Marinkovic et. al., 2010).* Quality and quantity of sugar yield can be influenced by defoliating and scalping operations during harvesting. Improper defoliating and scalping operations cause deterioration during storage because of large and exposed root surface. Leaf tissue left in the root crowns encourages regrowth in the pile reducing sugar content and increasing pile temperature. So, storing of beet roots should be in good condition.

5.2 Observation of sugar beet in processing plant in different phases of operation along with its by-products

Table 12 shows the pH value and polarisation % of diffusion water to horizontal diffuser RT and vertical diffuser BMA and water after pressing the exhausted cossettes from the diffuser. The samples were taken in four shifts in a day and analysed in the laboratory. The presented values of pH and polarisation % were calculated using the methods described in the 4.2.4 and 4.2.1 respectively. The average value of pH was found to be 5.1, 5.15 and 5.2 for diffusion water for horizontal diffuser RT, vertical diffuser BMA and water after pressing the wet pulp respectively. The pH value of diffusion water was found to be lower than pH of water after pressing because of acidification with sulphuric acid to achieve the conditions to avoid microbial activity during diffusion and also increase the pulp pressability. The sucrose content % was found to be 1.8, 1.7 and 2.7 for diffusion water for horizontal diffuser RT, vertical diffuser BMA and water after pressing the wet pulp respectively. The results were similar to the value range described in Asadi (2007) i.e. the sucrose content varies from 1-3%.

Table 12 Diffusion water and water after pressing the wet pulp

	Date	15/11/2010				16/11/2010				17/11/2010				18/11/2010				19/11/2010				Average of all 5 days
	Time	9:00	15:00	21:00	4:00	9:00	15:00	21:00	4:00	9:00	15:00	21:00	4:00	9:00	15:00	21:00	4:00	9:00	15:00	21:00	4:00	
Diffusion water RT	pH	5	5.05	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.05	5.1	5.1	5.1	5.09
	Pol (%)	1.8	1.6	1.7	1.7	1.8	1.7	1.6	1.6	1.7	1.7	1.8	1.8	1.8	1.7	1.8	1.8	1.7	1.5	1.7	1.7	1.71
Diffusion water BMA	pH	5.1	5.1	5.15	5.1	5.1	5.1	5.1	5.1	5.05	5.2	5.15	5.15	5.2	5.1	5.1	5.1	5.1	5.15	5.05	5.1	5.12
	Pol (%)	2.1	1.7	1.8	2	1.9	2	1.8	1.7	1.8	1.8	1.7	1.7	1.9	1.8	1.9	2.1	2	1.6	1.8	1.9	1.85
Water after pressing	pH	5.3	5.2	5.2	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.4	5.4	5.4	5.3	5.2	5.4	5.4	5.1	5.31
	Pol (%)	2.7	2.4	2.7	2.7	2.7	2.7	2.5	2.5	2.5	2.6	2.6	2.7	2.8	2.6	2.7	2.8	2.8	2.3	2.4	2.6	2.62

Table 13 and 14 shows the % of sugar content in the cossettes, in the pressed pulp and in the diffusion juice and also shows the parameter like pH, DS content, draft and purity of the diffusion juice in the two different diffusers RT and BMA. Sugar content in the cossettes is seemed to be 17-17.5 % in average. The average pH of the diffusion juice was found nearly 6 which is a natural pH value of beet juice *(Asadi 2007)* in both diffusers and also this is the optimum value where sucrose inversion to invert sugar is at lowest level.

Table 13 Diffusion juice after diffusion in horizontal diffuser RT96

Date	15/11/2010						16/11/2010					
Time	9:00	13:00	17:00	21:00	1:00	5:00	9:00	13:00	17:00	21:00	1:00	5:00
Digestion (%)	17.4			17.4			17.4			17		
Pol (%) in pressed pulp	2.8			2.4			2.5			2.4		
pH	5.9	5.9	5.9	5.9	6	6.1	6	5.9	5.9	6	5.9	6
Bx (%)	16.1	15.9	16.1	16.11	16.16	16.24	15.8	15.4	15.6	15.78	15.69	15.92
Pol (%)	14.75			14.8			14.5			14.5		
Q (%)	91.61			91.86			91.77			91.88		
Draft (%)	113.69			113.91			116.12			113.51		

Date	17/11/2010						18/11/2010					
Time	9:00	13:00	17:00	21:00	1:00	5:00	9:00	13:00	17:00	21:00	1:00	5:00
Digestion (%)	17			17			17.6			17.2		
Pol (%) in pressed pulp	2.9			2.4			2.4			2.6		
pH	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Bx (%)	16	15.6	15.9	15.7	15.4	15.6	15.8	15.7	15.6	16	15.9	16
Pol (%)	14.7			14.4			14.4			14.6		
Q (%)	91.87			91.71			91.13			91.25		
Draft (%)	111.2			114.3			118.47			113.8		

Date	19/11/2010						
Time	9:00	13:00	17:00	21:00	1:00	5:00	Average of all 5 days
Digestion (%)	17.4			17			17.24
Pol (%) in pressed pulp	2.5			2.5			2.54
pH	6	5.9	5.9	5.9	5.9	6	5.93
Bx (%)	15.96	15.6	15.64	15.8	16	15.9	15.83
Pol (%)	14.75			14.55			14.60
Q (%)	92.41			92.08			91.76
Draft (%)	114.15			112.97			114.21

The diffuser should not run with pH above 6.5 because it softens the cossettes and result in sugar loss in pulp. The average DS content % of the juice was found to be 15.83 and 16.96 and the average sugar content % was found to be 14.6 and 15.68 in RT and BMA diffusers respectively. These values for sugar content are similar to the values described by Haley (1973) in his patent but in regard with pH it was slightly lower than what he described i.e. 6.2-6.5.

Table 14 Diffusion juice after diffusion in vertical diffuser BMA

Date	15/11/2010						16/11/2010					
Time	9:00	13:00	17:00	21:00	1:00	5:00	9:00	13:00	17:00	21:00	1:00	5:00
Digestion (%)	17			18.1			17			17.4		
Pol (%) in pressed pulp	2.6			2.3			2.7			2.7		
pH	6	6	6	5.9	6.2	6.2	6.1	5.9	5.9	5.9	6	5.9
Bx (%)	17.3	17.2	17.1	17.14	16.89	17.05	16.9	16.6	16.5	17.07	16.9	17.13
Pol (%)	15.9			15.85			15.6			15.75		
Q (%)	91.9			92.47			92.3			92.26		
Draft (%)	103.23			110.93			105.08			106.61		

Date	17/11/2010						18/11/2010					
Time	9:00	13:00	17:00	21:00	1:00	5:00	9:00	13:00	17:00	21:00	1:00	5:00
Digestion (%)	17.6			17.7			17.3			17.6		
Pol (%) in pressed pulp	2.5			2.5			2.7			2.7		
pH	5.9	6	5.9	5.9	5.9	5.9	5.9	5.9	6	5.9	6	6
Bx (%)	17.15	17	17.4	16.8	16.7	16.8	16.7	16.7	16	17.3	17.2	17.2
Pol (%)	15.8			15.4			15.3			15.9		
Q (%)	91.83			91.66			91.61			91.9		
Draft (%)	108.17			111.28			109.1			106.87		

Date	19/11/2010						
Time	9:00	13:00	17:00	21:00	1:00	5:00	Average of all 5 days
Digestion (%)	17.8			17.4			17.49
Pol (%) in pressed pulp	2.7			2.4			2.58
pH	5.9	6	6	5.9	5.9	6	5.96
Bx (%)	16.95	17.01	16.79	17	17.2	17	16.96
Pol (%)	15.65			15.7			15.68
Q (%)	92.33			92.35			92.06
Draft (%)	109.85			107.38			107.85

Average draft of all shifts in 5 days shows that it is 114.21 and 107.85% for RT and BMA diffusers respectively. Arnold et. al., (2010) in his patent stated that the optimal draft is 105 to 110% whereas Asadi (2007) described it to be 110 to 120% in the context of today's beet sugar industries. Draft also depends upon the quality of beets processed. The draft should be increased in the case of damaged beets because they create difficulties during diffusion increasing the viscosity of the juice. The sugar content % in pressed pulp seemed to be 2.54 and 2.58% respectively in average of all shifts which is similar to range mentioned 2-5% by Reisig and Mannapperuma (2002) in their patent. The purity % was found to be 91.76 and 92.06 for RT and BMA diffusers respectively. Table 15 shows the contamination level of the diffusion juice, press water and the beet cossettes especially the formation of lactic acid. The main sources of microbial infection in beet sugar factories are the incoming beets, water used for unloading, transporting and washing beets and press water in the diffuser. In the tests it was found the level of lactic acid is higher in press water because the microorganisms get favourable temperature for growth therefore it should be heated before pumping back to the diffuser. Generally level of lactic acid above 150 mg/l is considered as indicator of bacterial growth in the diffuser. The pH value of juice was found in the range of 5.8-6.01 in the mixers and diffusers. The *Sugar Dobrovice* has also bio-ethanol plant along with it under *Sugar Company and distilleries TTD* and supplies diffusion juice for it too. The parameters of the diffusion juice to distillery are shown in the table 16. The pH value of the juice was found low in order to minimise the action of harmful bacteria during fermentation. The average DS content and sugar content of the juice were 18.32 and 16.93% respectively with an average purity 92.4%. Table 17 shows the % of sugar content in the juice from evaporator. Table 18 shows the results for alkalinity and pH value of the juice in different phases of purification. It was found to be 2.61% g CaO/l in average during pre-liming and 7.8, 0.78 and 0.17 % during main liming, 1st carbonation and 2nd carbonation respectively. The amount of lime used for pre-liming operation is higher resulting increment of the pH value than that of which is mentioned by Asadi (2007). But it is almost same to the range of value mentioned as in the *Web 22*. The main liming supports the destruction reactions where the invert sugars are decomposed into colored and acid products similarly amino acids into their ammonium salts. As described in *Web 22,* since the first carbonation sludge still contain particles of the colloidal matter precipitated during pre-liming, the final alkalinity of first carbonation should not be lower than the optimum value for pre-liming, to avoid redissolving again these particles, with resultant juice degradation. The alkalinity of the first carbonation juice should be choosed in between 0.8-1.0 g CaO/l. Any lower alkalinity value due to overgassing, while the sludge is still in contact with the juice, involves freeing coloring matter passing back to the juice. And if there the juice is not carbonated enough then it couldn't release sucrose from calcium sachharate which results difficulties during filtration and high sugar losses.

Table 15 Contamination

	Date	15/11/2010		16/11/2010		17/11/2010		18/11/2010		19/11/2010		Average of all 5 days
	Time	11:00	3:00	11:00	3:00	11:00	3:00	11:00	3:00	11:00	3:00	
Mixer RT	pH	5.9	6.1	5.8	6	5.9	5.9	5.9	5.9	6	6	5.925
	L.A (mg/l)	112	113	134	121	147	95	114	90	85	105	115.75
Mixer BMA	pH	6	6.2	5.9	6	6	6	6	6	6	6	6.01
	L.A (mg/l)	83	104	102	89	95	71	66	69	68	84	84.88
Diffuser RT96	pH	5.9	5.9	5.8	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.85
	L.A (mg/l)	120	124	134	154	143	139	151	138	104	112	137.88
Diffuser RT93	pH	5.9	5.9	5.75	5.8	5.9	5.8	5.8	5.8	5.9	5.8	5.83
	L.A (mg/l)	113	104	156	137	148	127	130	124	106	114	129.88
Diffuser BMA	pH	5.9	6	5.8	5.9	5.9	5.9	5.8	5.9	5.9	5.9	5.89
	L.A (mg/l)	116	118	112	108	115	104	98	114	81	96	110.63
Press water	pH	5.3	5.4	5.4	5.3	5.3	5.2	5.2	5.4	5.1	5.1	5.31
	L.A (mg/l)	155	140	117	123	143	138	144	151	133	139	138.88
Beet slices	L.A (mg/l)	26	23	20	22	21	20	20	22	19	24	21.75

Table 16 Diffusion juice for distillery

Date	15/11/2010						16/11/2010					
Time	7:00	12:00	17:00	19:00	23:00	3:00	7:00	12:00	17:00	19:00	23:00	3:00
pH	3.5	3.5	3.5	3.5	3.6	3.6	3.5	3.5	3.5	3.6	3.5	3.5
Bx (%)	18.2	18.3	18.15	18.36	18.03	18.13	17.9	17.7	17.9	18.24	18.53	18.56
Pol (%)	16.8	17	16.8	16.9	16.65	16.85	16.5	16.4	16.5	16.9	17.15	17.25
Q (%)	92.3	92.89	92.56	92.04	92.34	92.93	92.17	92.65	92.17	92.65	92.55	92.94

Date	17/11/2010						18/11/2010					
Time	7:00	12:00	17:00	19:00	23:00	3:00	7:00	12:00	17:00	19:00	23:00	3:00
pH	3.5	3.4	3.5	3.5	3.4	3.5	3.5	3.4	3.5	3.5	3.4	3.4
Bx (%)	18.5	18.4	18.6	18.25	18.1	18.2	18.2	18.5	18.3	18.55	18.45	18.6
Pol (%)	17.2	17	17.2	16.8	16.7	16.85	16.75	16.95	16.85	17.05	17.05	17.2
Q (%)	92.97	92.39	92.47	92.05	92.26	92.58	92.03	91.62	92.07	91.91	92.41	92.47

Date	19/11/2010						Average of all 5 days
Time	7:00	12:00	17:00	19:00	23:00	3:00	
pH	3.5	3.5	3.4	3.4	3.5	3.4	3.48
Bx (%)	18.49	17.99	18.35	18.5	18.65	18.9	18.32
Pol (%)	17.1	16.55	16.95	17.15	17.2	17.55	16.93
Q (%)	92.48	91.99	92.37	92.7	92.22	92.85	92.4

Table 17 Juice from third evaporator

Date	15/11/2010		16/11/2010		17/11/2010		18/11/2010		19/11/2010		Average of all 5 days
Time	10:00	20:00	10:00	20:00	10:00	20:00	10:00	20:00	10:00	20:00	
Pol (%)	37.65	38.85	38.35	37.8	39.2	39.4	36.9	37.35	37.7	38.1	38.13

Table 18 Alkalinity

	Date	15/11/2010			16/11/2010			17/11/2010			18/11/2010		
	Time	9:00	15:00	1:00	9:00	15:00	1:00	9:00	15:00	1:00	9:00	15:00	1:00
Pre- liming	g CaO/l	2.7	2.7	2.8	2.5	2.3	2.7	2.7	2.8	2.6	2.4	2.7	2.8
	pH	11.1	11.2	11.2	10.9	11	11	11.3	11.2	11.2	11.2	11.1	11.2
Main liming	g CaO/l	7.8	7.9	7.8	7.9	7.7	7.8	7.9	7.7	7.9	7.8	7.8	7.9
	pH	11.6	11.7	11.8	11.8	11.7	11.6	11.6	11.8	11.8	11.6	11.6	11.7
Total	g CaO/l	14.7		14.8	14.8		14.9	15.2		14.9	15.2		15.1
1st Carbonation	g CaO/l	0.8	0.79	0.78	0.76	0.79	0.8	0.78	0.78	0.78	0.78	0.79	0.78
	pH	10.7	10.7	10.7	10.6	10.7	10.6	10.8	10.5	10.9	10.7	10.8	10.9
2nd Carbonation	g CaO/l	0.15	0.15	0.15	0.17	0.17	0.17	0.18	0.19	0.18	0.16	0.19	0.17
	pH	8.7	8.8	8.9	8.7	8.8	8.8	8.9	9	8.8	8.7	8.9	8.8

	Date	15/11/2010			Average of all 5 days
	Time	9:00	15:00	1:00	
Pre-liming	g CaO/l	2.5	2.4	2.5	2.61
	pH	11.2	11	11.1	11.13
Main liming	g CaO/l	7.8	7.8	7.8	7.8
	pH	11.6	11.6	11.6	11.67
Total	g CaO/l		15.3	15.3	15.02
1st Carbonation	g CaO/l	0.78	0.77	0.77	0.78
	pH	10.7	10.6	10.8	10.71
2nd Carbonation	g CaO/l	0.17	0.17	0.18	0.17
	pH	8.8	9	9.1	8.85

Table 19 shows the results for sugar content in the sludge in five different filter presses. The high sugar loss in the sludge was seen in the second shift of the first day. Generally the sugar content in the sludge is found to be 0.5% in the literatures which is more or less similar to the average of all days in the result. Table 20 shows the density and sugar content of the milk of lime. Density was found to be 21.05˚Be in average and sugar content was 3.57 % in average. Parameters before sulphitation and after sulphitation of thin juice are shown in the tables 21 and 22. The pH seems to be in the average of 8.89 % and the hardness 66.67 mg CaO/100g DS in average. The hardness in the range 50-200 mg CaO/100g DS is considered to be normal in the beet industries as it depends upon the quality of sugar beet processed *(Asadi 2007)*. The color of thin juice is 2083 IU in average in the case of thin juice before sulphitation and 2024.6 IU in the case of thin juice after sulphitation which is similar to the range color of 1300 to 2500 for thin juice by conventional lime purification method by Madsen et. al., (1984) in their patent.

Table 19 Lime sludge

Date	15/11/2010						16/11/2010					
Time	8:00	11:00	16:00	22:00	0:00	3:00	8:00	11:00	16:00	22:00	0:00	3:00
Filter press number	4	1	3	2	4	5	1	3	4	1	2	4
Sugar content in the sludge (%)	1.30	2.6	0.65	0.3	0.1	1.2	1.15	0.15	1.65	0.1	0.2	0.1

Date	17/11/2010						18/11/2010					
Time	8:00	11:00	16:00	22:00	0:00	3:00	8:00	11:00	16:00	22:00	0:00	3:00
Filter press number	4	2	3	2	3	4	5	3	2	4	2	3
Sugar content in the sludge (%)	0.3	0.4	0.2	1.6	0.2	0.35	0.6	0.15	0.1	0.55	1.15	0.3

Date	19/11/2010						Average of all 5 days
Time	8:00	11:00	16:00	22:00	0:00	3:00	
Filter press number	5	2	3	3	4	2	
Sugar content in the sludge (%)	0.10	0.15	0.15	0.15	0.7	0.5	0.57

Table 20 Milk of lime ($Ca(OH)_2$)

Date	15/11/2010				16/11/2010				17/11/2010			
Time	8:00	11:00	16:00	22:00	8:00	11:00	16:00	22:00	8:00	11:00	16:00	22:00
Density (˚Be)	21	21	21	21	21	21	21	21	22	21.5	21	21
Pol (%)	3.50	3.8	3.7	3.8	3.5	3.6	3.7	3.7	3.7	3.7	3.6	3.6

Date	17/11/2010				18/11/2010				Average of all 5 days
Time	8:00	11:00	16:00	22:00	8:00	11:00	16:00	22:00	
Density (˚Be)	20.5	21	21	21	21	21	21	21	21.05
Pol (%)	3.6	3.2	3.3	3.2	3.4	3.6	3.6	3.5	3.57

Table 21 Thin juice before sulphitation

Date	15/11/2010			16/11/2010			17/11/2010			18/11/2010		
Time	9:00	15:00	23:00	9:00	15:00	23:00	9:00	15:00	23:00	9:00	15:00	23:00
pH	8.8	8.8	8.8	8.7	8.8	8.9	9	8.9	9	8.9	8.9	8.9
Hardness mg CaO/100g DS	76	77	70	64	56	58	62	62	53	65	69	79
Color (icumsa c420)	2091			2047			2096			2122		

Date	19/11/2010			Average of all 5 days
Time	9:00	15:00	23:00	
pH	9.1	8.9	8.9	8.89
Hardness mg CaO/100g DS	83	76	50	66.67
Color (icumsa c420)	2059			2083

Color formation in the thin juice is related to different factors like temperature, pH and reactions of organic non sugars e.g. Milliard reaction. Table 23 shows the results for decalcification of thin juice in two columns. It is done after sulphitation process in the *Sugar Dobrovice* which uses three columns where one of them is used for regeneration of resins. Ultimate result of juice decalcification depends on beet composition as well as processing conditions. The table shows that the average hardness of the juice while entering the columns is 108.4 mg CaO/l and 21.8 mg CaO/l when leaving the columns which are more or less similar to data found by Coca et. al., (2009). The amount of hardness in two different columns is also shown in the table. Values after evaporation of thin juice in multi effect evaporators are shown in table 24. The average % of DS content in the thick juice was found 68.68. Similarly the average % of sugar content was 58.38 resulting the average purity of 93.23% .The pH value was found to be 9.19 in average. Alkalinity and pH drop slightly during evaporation is considered to be usual. Color seemed to be increased in thick juice compared to thick juice. It is because of milliard reaction which is favourable under alkine and high temperature. Turbidity was found to be 0.6 in average of all shifts of all days. Table 25 shows the DS content of sugar beet pulp before and after pressing, pellets, water loss during drying, sugar content in pellets and ash content in pellets. The result shows that the DS content was found to be 12.25 and 28.96% on average before and after pressing. The sugar content was found 7.23% and ash content to be 7.51%. Similar values are also mentioned in Asadi (2007) for sugar content but are slightly different for ash content. The sugar content in the pellets could be high in the case that it is fixed with molasses before pelletizing.

Table 22 Thin juice after sulphitation

Date	15/11/2010			16/11/2010			17/11/2010			18/11/2010			19/11/2010			Average of all 5 days
Time	9:00	15:00	23:00	9:00	15:00	23:00	9:00	15:00	23:00	9:00	15:00	23:00	9:00	15:00	23:00	
Bx (%)	15.8	16.4	16.2	15.9	15.9	16.04	16	15.9	16	15.8	15.6	15.9	16.26	15.94	16.1	15.98
Pol (%)	14.7			14.8			14.8			14.7			15.15			14.83
Q (%)	93.03			93.08			92.5			93.03			93.17			92.96
pH	8.9	8.9	8.9	8.8	8.9	8.8	8.9	8.8	8.9	8.9	8.8	8.8	9	8.8	8.8	8.86
Hardness mg CaO/100g DS	74	76	66	62	54	56	60	59	50	63	67	77	81	73	47	64.33
Color (icumsa c420)	2061			2029			2082			2071			1880			2024.6

Tables 26, 27 and 28 show the values of different parameters like pH, sugar content, DS content and purity of standard liquor, massecuite ‘A’ and sugar ‘A’ respectively. Tables 29, 30 and 31 shows the pH, sugar content, DS content, color and purity of high

Table 23 Decalcification

Date	15/11/2010				16/11/2010				17/11/2010				18/11/2010				19/11/2010				Average of all 5 days
	mg CaO/l				mg CaO/l				mg CaO/l				mg CaO/l				mg CaO/l				
Time	11:00	17:00	23:00	5:00	11:00	17:00	23:00	5:00	11:00	17:00	23:00	5:00	11:00	17:00	23:00	5:00	11:00	17:00	23:00	5:00	
Thin juice entering	126	132	112	128	106	88	96	84	102	100	84	94	106	112	132	148	138	124	80	76	108.4
Kolona 110	18	20	20	24		20		20	18		16	20	20	22	22		24		20		20.29
Kolona 115		18		26	20		24		16	18	22			18	20	22	30	30	22	22	22
Kolona 120	20		26		16	22	22	24		18	18		20			22		28		18	21.17
Thin juice exiting	20	18	24	24	20	22	22	24	18	18	18	22	22	20	22	22	30	28	22	20	21.8

green syrup, white syrup (wash syrup) and massecuite ‘B’. Similarly in tables 32, 33 and 34 the values of mentioned parameters are given for sugar ‘B’, black syrup and sugar ‘C’. Humidity of sugar before and after drying and its turbidity is given in table 35. Turbidity is localized at the surface of sucrose crystals in the form of micro-crystals of calcium oxalates. Inside sugar crystals, complexes of calcium oxalates and macromolecules might be at the origin of turbidity (Roge et. al., 2007). The quality of sugar is given in the table 36 showing the values for color in the sugar solution, ash content, color in the sugar crystal and total nitrogen level (CNL). The values obtained are converted into the European points to analyse the standard acceptable according to the EU legislation. The result shows that they meet all the requirements necessary for human consumption set by the legislation. Distribution of crystal sizes of sugar is given in table 37. As much as the coefficient of variation is low, more uniform crystals sizes can be achieved.

Table 24 Thick juice

Date	15/11/2010						16/11/2010					
Time	7:00	12:00	17:00	19:00	23:00	3:00	7:00	12:00	17:00	19:00	23:00	3:00
Bx (%)	63.90	63.40	64.5	62.19	63.26	62.96	63.9	64.8		61.43		60.95
Pol (%)	59.50						59.65					
Q (%)	93.11						93.34					
pH	9.3	9.3	9.2	9.3	9	9.2	9.1	9.3		9.4		9.3
Hardness mg CaO/100g DS	13	12	12	12	12	14	11	12		13		14
Color (icumsa c420)	2766						2653					
Turbidity	0.1							1.3				

Date	17/11/2010						18/11/2010					
Time	7:00	12:00	17:00	19:00	23:00	3:00	7:00	12:00	17:00	19:00	23:00	3:00
Bx (%)	61.5	64	62.2	61.1	62.8		61.3	61	62.6	61.8	63.2	
Pol (%)	57.17						57.2					
Q (%)	92.95						93.31					
pH	9.3	9.3	9.2	9	9.2		9.4	8.8	9.1	9.3	9.1	
Hardness mg CaO/100g DS	12	12	13	11	12		14	15	15	14	15	
Color (icumsa c420)		2296						2246				
Turbidity		0.2						0.2				

Date	19/11/2010						Average of all 5 days
Time	7:00	12:00	17:00	19:00	23:00	3:00	
Bx (%)	62.50	62.77	62.45	62.8	63.7		62.68
Pol (%)	58.40						58.38
Q (%)	93.44						93.23
pH	8.9	9.4	9.1	9.3	9		9.19
Hardness mg CaO/100g DS	16	17	16	13	12		13.28
Color (icumsa c420)	2415						2475.20
Turbidity		1.2					0.60

Table 25 DS content in before and after pressing the exhausted cossettes and drying pellets

Date	15/11/2010		16/11/2010		17/11/2010		18/11/2010		19/11/2010		Average of all 5 days
Time	8:00	21:00	8:00	21:00	8:00	21:00	8:00	21:00	8:00	21:00	
DS before pressing BMA (%)	12.2	12.2	12	12.3	12.1	12.7	12.2	12.4	12.1	12.3	12.25
DS before pressing RT96 (%)	12	12.6	11.8	11.3	11.5	11.5	11.7	11.4	10.7	11.2	11.57
DS before pressing RT93 (%)	11.4	11.4	11.1	10.3	10.8	10.6	11.1	11	10.7	11	10.94
DS after pressing (%)	29.5	28.9	29.1	28.5	29.5	28.2	29.1	28.9	28.9	28.9	28.95
Water loss from pellets (%)	11.5	11.5	11.4	11.6	11.7	11.6	11.6	11.5	11.5	11.7	11.56
Dry mass in pellet (%)	88.5	88.5	88.6	88.4	88.3	88.4	88.4	88.5	88.5	88.3	88.44
Sugar content in pellet (%)	7.6	6	6.8	7.2	7	7.2	6.9	7.4	8.2	8	7.23
Ash content in pellet (%)		7.17	7.58		7.2		7.19		8.42		7.51

Table 26 Standard liquor 74˚Bx

Date	Bx (%)	Pol (%)	Q (%)
15/11/2010	70.9	67.2	94.78
16/11/2010	71.24	67.8	95.17
17/11/2010	71.3	67.6	94.81
18/11/2010	70.8	67.4	95.19
19/11/2010	71.1	67.5	94.93
Average	71.07	67.50	94.98

Table 27 Massecuite ‘A’

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	82.14	72.2	87.89	9.2
16/11/2010	81.9	71.4	87.17	9.1
17/11/2010	81.5	71.6	87.85	9
18/11/2010	81.6	71.5	87.62	9
19/11/2010	81.6	70.6	86.51	9.1
Average	81.75	71.46	87.41	9.08

Table 28 Sugar ‘A’

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	92.6	87.9	94.92	9.2
16/11/2010	92.78	88.4	95.27	9.1
17/11/2010	91.5	87.1	95.19	9
18/11/2010	92	87.6	95.21	9
19/11/2010	93	88.4	95.05	9.1
Average	92.38	87.88	95.13	9.08

Table 29 High green syrup

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	80.5	72.1	89.56	9.2
16/11/2010	79.1	71.3	90.13	9.3
17/11/2010	80.8	72.2	89.35	9.2
18/11/2010	80.8	72	89.1	9.2
19/11/2010	80.78	71.9	89	9
Average	80.40	71.90	89.43	9.18

Table 30 White syrup (wash syrup)

Date	Bx (%)	Pol (%)	Q (%)	pH	Color (icumsa c420)
15/11/2010	73.4	69.8	95.09	9.1	2454
16/11/2010	75.68	72.3	95.53	9.1	2513
17/11/2010	74.8	71.1	95.05	9.1	2358
18/11/2010	75.2	71.9	95.61	9	2444
19/11/2010	74.98	71.3	95.09	8.9	2426
Average	74.81	71.28	95.27	9.04	2439.00

Table 31 Massecuite ‘B’

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	83.1	66.91	80.51	9.1
16/11/2010	83.8	65.7	78.4	9.1
17/11/2010	83.2	65.3	78.48	9.1
18/11/2010	83.8	65.4	78.04	9.1
19/11/2010	84.56	65.5	77.45	8.9
Average	83.69	65.76	78.58	9.06

Table 32 Sugar ‘B’

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	91.4	82.8	90.59	9.1
16/11/2010	91.8	82.7	90.08	9.1
17/11/2010	91.8	82.2	89.54	9.1
18/11/2010	92	81.2	88.26	9.1
19/11/2010	92.3	82.1	88.94	8.9
Average	91.86	82.20	89.48	9.06

Table 33 Black syrup

Date	Bx (%)	Pol (%)	Q (%)	pH
15/11/2010	77.2	63.2	81.86	9.2
16/11/2010	78.4	63.3	80.73	9.2
17/11/2010	78.6	63.6	80.91	9.3
18/11/2010	79.6	64.2	80.65	9.2
19/11/2010	77.72	61.8	79.51	9
Average	78.30	63.22	80.73	9.18

Table 34 Sugar ‘C’

Date	Bx (%)	Pol (%)	Q (%)	pH	Color (icumsa c420)	Turbidity
15/11/2010	93.26	76.2	81.7	9.1	1897	0.3
16/11/2010	93.78	76.3	81.36	9.1	1527	0.1
17/11/2010	93.3	76.2	81.67	9.1	1432	0.1
18/11/2010	93.6	76	81.19	9.1	1374	0.1
19/11/2010	94.2	75.4	80.04	9	1726	0.1
Average	93.63	76.02	81.19	9.08	1591.20	0.14

Table 35 Humidity of sugar (units in %)

Date	before drying	after drying	during storage	turbidity
15/11/2010	0.497	0.042	0.042	5
16/11/2010	0.404	0.048	0.048	3
17/11/2010	0.529	0.034	0.034	4
18/11/2010	0.558	0.035	0.035	3
19/11/2010	0.413	0.031	0.031	4
Average	0.480	0.038	0.038	3.8

Table 36 Sugar quality

	Date	15/11/2010			16/11/2010			17/11/2010			18/11/2010			19/11/2010			Average
	Shift	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	All shifts
	Color	20	19	19	20	20	20	19	19	20	19	18	19	21	19	20	19.47
in units	Type	1	0.9	0.9	1	1.1	0.8	0.9	0.9	1	1	0.9	0.9	1	0.9	1	0.95
	Ash	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0
	Color	2.67	2.53	2.53	2.67	2.67	2.67	2.53	2.53	2.67	2.53	2.4	2.53	2.8	2.53	2.67	2.60
European points	Type	2	1.8	1.8	2	2.2	1.6	1.8	1.8	2	2	1.8	1.8	2	1.8	2	1.89
	Ash	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
	Total	6.89	6.56	6.56	6.89	7.09	6.49	6.56	6.56	6.89	6.76	6.42	6.56	7.02	6.56	6.89	6.71
	CNL	4	3	2	5	4	6	5	4	5	3	3	5	5	3	3	4

Table 37 Sorting (units in %)

Date	sieve							
	1 mm	0.8 mm	0.63 mm	0.40 mm	0.315 mm	0.16 mm	medium size crystal (mm)	Coefficient of variation (%)
15/11/2010	1.1	6.4	31.8	37.5	10.8	10.6	0.55	36.25
16/11/2010	0.7	6.3	24.3	42.4	11	13	0.53	38.13
17/11/2010	1	4.3	28	43.8	10.8	10.8	0.54	34.7
18/11/2010	0.6	3.9	26.4	43.1	12.8	11.3	0.53	35.82
19/11/2010	0.8	3.8	28.8	40.2	12.2	11.3	0.53	37.7
Average	0.84	4.94	27.86	41.4	11.52	11.4	0.536	36.52

VI. Conclusions

As sugar processing industry involves a large number of processing stations (diffusion, purification, evaporation etc), during my whole work different phases of sugar beet processing have been observed. Sugar industry besides its co products, it produces various by-products in particular stations during the entire operations. During my stay in the factory *Sugar Dobrovice* these by-products were also studied. Samples were taken from the factory in different stations and brought to the laboratory for analysis. All the analysis was done according to the norms and legislations. Especially the characteristics of sugar beet with different parameters like pH, temperature, DS content, sugar content etc were the main points to focus at the time of the study. The goal of sugar factory i.e. to achieve the final product (white sugar) should have certain standards that meet the requirements of the legislation. In order to achieve that quality of sugar, there should be optimum conditions to maintain in each stations of the sugar factory. So it is important job in the every sugar factory to observe the samples from various stations either they are achieving the optimum criterion or not. During analysing the parameters like color of sugar, ash content etc, it was found that they meet the criteria required for human consumption. As the purification station is oftenly considered as a heart of sugar factory, the product from this station has significant effect on producing quality sugar. Various tests like alkalinity, hardness, color etc were performed. Characteristics of standard liquor, massecuites, high green syrup, white syrup, black syrup, sugar A, B and C were also observed. The by-products are also the subject of interest in sugar industry. Characteristics of pulp before and after drying, pelletizing and lime sludge etc were also observed. It was my misfortune that the tests for molasses were not possible to perform in the laboratory, *Sugar Dobrovice*. Nevertheless the characteristics of it are mentioned in the backgrounds theoretically in chapter 2.6.4. It would have been better to include the practical analysis of molasses as it is one of the most important by-products of sugar beet industry. In future, it will be my interest of subject to study on molasses practically.

VII. References

1. ASADI M., 2007, “Beet Sugar Handbook” ISBN-13: 978-0-471-76347-5 and ISBN-10: 0-471-76347-0, 866 pages

2. BEILECKI S., TRAMPER J. and POLAK J., 2000, “Food biotechnology” ISBN: 0-444-50519-9, 430 pages

3. BUKVIC S., KRALIK Z., MILAKOVIC D., BOGUT Z. and MILOS I., 2008. “Employment of sugar beet head for biogas production” CAB Abstracts Cereal Research Communications, Suppl. 5, Pages 575-578, AN: 20103108702

4. CHEESMAN O. D., 2004, “Environmental impacts of sugar production” ISBN: 0 85199 981 6, 255 pages

5. COCA M., GARCIA M. T., GONZALEZ G. , PENA M. and GARCIA J. A., July 2004. “Study of coloured components formed in sugar beet processing” Food Chemistry, Volume 86, Issue 3, Pages 421-433

6. COCA M., MATO S., BENITO G. G., URUENA M. Á. and GARCIA-CUBERO M. T., April 2010. “Use of weak cation exchange resin Lewatit S 8528 as alternative to strong ion exchange resins for calcium salt removal” Journal of Food Engineering Volume 97, Issue 4, Pages 569-573

7. DECLOUX M., BORIES A., LEWANDOWSKI R., FARGUES C., MERSAD A., LAMELLOISE M. L., BONNET F., DHERBECOURT B., OSUNA L. N., 2002. “Interest of electrodialysis to reduce potassium level in vinasses, Preliminary experiments” Desalination, 146 (2002), Pages 393-398. <http://tinyurl.com/642ecth>

8. DELGADO A.V. and CASANOVA C.A., 2001, “Sugar Processing and by products of the sugar industry” ISBN: 92-5-104570-4, 132 pages

9. DRAYCOTT A. P., 2006, “Sugar Beet” ISBN-10: 1-4051-1911-X, ISBN-13: 978-1-4051-1911-5, 474 pages

10. ERGUN M. and MUTLU S. F., July 2000. “Application of a statistical technique to the production of ethanol from sugar beet molasses by *Saccharomyces cerevisiae*” Bioresource Technology, Volume 73, Issue 3

11. ESSIA NGANG J.J., LETOURNAEU F., and VILLA P., 1989. “Alcoholic fermentation of beet molasses: effects of lactic acid on yeast fermentation parameters” Applied and Microbial Biotechnology, Pages 125-128

12. FAZAELI H., KORD-NEJAD I., KHAYYAT A., 2010. “Utilization of sugar beet-top ensiled with sugar cane bagasse and sugar cane molasses in the diet of lactating buffalo” CAB Abstracts Revista Veterinaria, Suppl. 1, Pages 713-716, AN: 20103164131

13. FRAPE D., 2010, “Equine Nutrition and Feeding” 4th edition, ISBN 978-1-4051-9546-1, 512 pages

14. HACKING A. J., 1987, “Economics Aspects of Biotechnology” ISBN: 0-521-25893-6, 318 pages

15. ISMAIL A. I., TANZER J. M. and DINGLE J. L., “Current trends of sugar consumption in developing societies” Article first published online: 29 MAY 2006

16. JORDENING H. and WINTER J., 2005, “Environmental biotechnology: Concepts and Applications” ISBN: 3-527-30585-8, 463 pages

17. KENT J. A., 2003, “Riegel’s Handbook of Industrial Chemistry” ISBN: 0-306-47411-5, 1373 pages

18. KING J. and MAY M. , 2007. British sugar beet review “Soil management for sugar beet” Volume 75 no. 3

19. KRYVORUCJKO V., MACMULLER A., BODIROZA V., AMON B. and T. AMON, April 2009. “Anaerobic digestion of by-products of sugar beet and starch potato processing” Biomass and Bioenergy Volume 33, Issue 4, Pages 620-627 published online 26 November 2008

20. LEWIS M. J. and GRANDISON A. S., 1996, “Separation Process in the food and technology industries: Principles and Applications” ISBN-13: 978-1-85573-287-2, 290 pages

21. MARINKOVIC B., CRNOBARAC J., JACIMOVIC G., RAJIC M., LATKOVIC D. and ACIN V., 2010 “Sugar yield and technological quality of sugar beet at different levels of nitrogen fertilization” Research Journal of Agricultural Science 42 (1)

22. Mathlouthi M., 2000, “Highlights of twentieth century progress in sugar technology and the prospects for the 21st century” ISBN: 1-883326-09-5

23. MCDONELL G. and RUSSELL AD, 1999 “Antiseptics and disinfectants: activity, action, and resistance” Clin. Microbial Rev. Jan 12(1), Pages 147-179

24. MUDOGA H.L., YUCEL H., KINCAL N. S., June 2008. “Decolorization of sugar syrups using commercial and sugar beet pulp based activated carbons” Biological Abstracts Bioresource Technology, Pages 3528-3533, AN: BACD200800222352

25. ONAL Y., AKMIL-BASAR C., SARICI-OZDEMIR C., ERDOGAN S., April 2007. “Textural development of sugar beet bagasse activated with $ZnCl_2$” Biological Abstracts Journal of Hazardous Materials, Pages 138-143, AN: BACD200700210491

26. PAYAM N., HASSAN T. S. and AMINI H., March 2009. “Effects of sugar beet industrial wastewater towards soil hydraulic properties” Research Journal of Chemistry and Environment, Vol 13(1)

27. PRYOR S., NAHAR N., RORICK R., May 2010. “Enzymatic Pre-treatment of Sugar Beet Pulp for Ethanol Production” North Dakota State University, Published by the Department of Agricultural and Biosystems Engineering, Last updated: Thursday, May 06, 2010

28. ROGE B., BENSOUISSI A. and MATHLOUTHI M. , 2007. “Effect of calcium on white sugar turbidity” by Sugar Industry 132, No. 3, Pages 170-174

29. SAREC P., SAREC O., SRB K., DOBEK T. 2009. “Analysis of sugar beet production depending on various soil preparation technologies” Inzynieria Rolnicza. Nr 1 (110). s. Pages 273-280

30. SARKA E., BUBNIK Z., KADLEC P. and VESELA-TRILCOVA A., July 2008 “The particle size of carbonation mud, and possibilities for influencing it” Journal of Food Engineering, Volume 87, Issue 1, Pages 45-50

31. SHARMA R. D., 1997, “Handbook of Agriculture” Indian Council of Agricultural Research, New Delhi7. 975-996 pages

32. SMUTKA L., POKORNA I. and PULKRABEK J., 2011. “The world production of the sugar crops” Czech SUGAR and SUGAR BEET JOURNAL, Vol. 127 <http://www.cukr-listy.cz/on_line/2011/PDF/78-82.pdf>

33. TAHERZADEH M. J., ADLER L. and LIDEN G., July 2002. “Strategies for enhancing fermentative production of glycerol a review” Volume 31, Issues 1-2, Pages 53-66

34. TREHAN K., 1990, “Biotechnology” ISBN: 81-224-0129-5, 286 pages <http://www.angostura.com/History/TheRumProcess/TheTechnologyofRumMaking/tabid/122/Default.aspx>

35. URBANIEC K., March 2004. “The evolution of evaporator stations in the beet-sugar industry” Journal of Food Engineering, Volume 61, Issue 4

36. VOGEL H. C. and TODARO C. L., 1997, “Fermentation and biochemical engineering handbook: principles, process design, and equipment” ISBN: 0-8155-1407-7, 801 pages

37. WAITES M. J., MORGAN N. L., ROCKEY J. S. and HIGTON G., 2001, “Industrial Microbiology: An Introduction” ISBN: 0-632-05307-0, 288 pages

38. WANG Z., ZHUGE J., FANG H., PRIOR B. A., June 2001. “Glycerol production by microbial fermentation a review” by Volume 19, Issue 3, Pages 201-223

39. WILLIAMS P. A. and PHILLIPS G. O., 2009, “Gums and Stabilizers for the Food Industry 15” ISBN: 978-1-84755-199-3, 470 pages

40. WILSON J., 2008, “The Model Railroader's Guide to Industries along the Tracks 3” ISBN: 978-0-89024-710-3, 87 pages

41. WYMAN C. E., 1996, “Handbook on Bioethanol; Production and Utilizations” ISBN: 1-56032-553-4, 424 pages

42. YADAV R.L. and SOLOMON S., 2006. “Potential of Developing Sugarcane By-product based industries in India” Sugar Tech 8(2&3) 104-111

Patents

1. ALBERT R. G., December 1967, “Crystallization of sugar” Patent No: 3356532

2. BENTO LUIS R. S. M. and REIN P. W., November 2008, “Chemical Regeneration of Activated Carbon” Patent No: 20080286193

3. HALEY B, “Process for purifying sugar beet diffusion juice” Patent No: 3745016

4. JOCHEN A., STEFAN F., THOMAS M. and TIMO S., April 2010, “Extraction of constituents from sugar beet chips” Patent No: 7695566

5. KEARNEY M. M., VADIM K., PETERSON K. R. and LARRY V., November 1995, “Sugar beet juice purification process” Patent No: 5466294

6. KRISTIAN E., JUHA N. and JOUKO V., November 2004, “Process for the crystallization of non-sucrose substances” Patent No: 6821339

7. MADSEN R. F., NIELSEN W. K, STEEN K., 1984, “Method of purifying sugar juice prepared by extraction of a sugar beet material” Patent No: 4432806

8. REISIG R. C., MANNAPPERUMA J. D., 2002 “Process for production of purified beet juice for sugar manufacture” Patent No: 6387186

9. SASKA M. and XAIVEIR L., August 1995 "Process for softening a sugar-containing aqueous solution, such as sugar juice or molasses” Patent No: 5443650

10. TOTH L. and CONWAY M. R., January 1989 "Beet juice purification system" Patent No: 4795494

11. TOTH L. and SAGASER J. E., January 1996 “Method for purifying beet juice using recycled materials" Patent No: 5480490,

12. WINSTROM-OLSEN and BJARNE, August 1985, “Process and apparatus for the production of sugar thick juice for the manufacture of sugar” Patent No: 4534800

13. WONG E. and BREGOL M., 2000, “Use of sugar beet pulps for making paper or cardboard” Patent No: 6074856

Internet

1. Web 1, < www.ext.colostate.edu/foodnut/09301.html>

2. Web 2, <ec.europa.eu/agriculture/capreform/sugar/infopack_en.pdf>
“The European Sugar Sector, A long term competitive future” Sept. 2006

3. Web 3 <http://tinyurl.com/68auxf3> Google docs: “Sugar_industry”

4. Web 4, <http://tinyurl.com/6h9v7ke> Google docs: “Silver Wedge: The sugar beet industry in Fort Collins”

5. Web 5, <http://tinyurl.com/6caz6yj> “CBI Market”

6. Web 6, <www.ienica.net/crops/sugarbeet.html> “Sugar Beet”,

7. Web 7, <http://tinyurl.com/6c6bey6> “Crop profile for sugar beets in Montana”

8. Web 8, <www.solarnavigator.net/solar_cola/sugar_beet.html> “Sugar beet crops”

9. Web 9, <http://tinyurl.com/5wssgzp> Google docs: “AP-42 CH 9.10.1.2: Sugar beet processing”

10. Web 10, <www.gewater.com/pdf/tech33.pdf> “Technical Bulletin, Understanding the sugar beet process”

11. Web 11
<http://www05.abb.com/global/scot/scot211.nsf/veritydisplay/821981bad2c99ab8c1256e6700451fc8/$file/3kde010003r3001.pdf> “Process Automation Examples from Various Plant Stations in a Beet Sugar Factory”

12. Web 12, <http://www.iupac.org/publications/pac/pdf/1972/pdf/2901x0113.pdf> “Measures against water pollution in beet sugar processing industries” by R. DE YLETTER

13. Web 13, <http://rcrec-ona.ifas.ufl.edu/pdf/publications/molasses-general-considerations.Pdf> MOLASSES-GENERAL CONSIDERATIONS by Dr. Leo V. Curtin

14. Web 14 <http://tinyurl.com/6caz6yj> "CBI MARKET SURVEY: THE SUGARS MARKET IN THE EU" July 2009

15. Web 15, < http://en.wikipedia.org/wiki/Alcoholic_beverage#cite_note-icap-0>

16. Web 16, < http://en.wikipedia.org/wiki/Ethanol#Historical_uses>

17. Web 17, < http://tinyurl.com/6xet5e4>

18. Web 18, < http://tinyurl.com/5s8nlor>

19. Web 19, <http://tinyurl.com/6jzqqzn web 20>

20. Web 20, <http://www.cukr-listy.cz/lc-statistika.html>

21. Web 21, <http://www.caobisco.com/doc_uploads/legislation/2001-111-EN.pdf>

22. Web 22, <http://www.sugarxperts.com/dokus/SIT1JuicePurification.pdf>
"Fundamentals of Beet Juice Carbonatation" by L briones 01.2005

23. BAEZ-SMITH C., 2006 "Anaerobic Digestion of Vinasse for Production of Methane in the Sugar Cane Distillery" <http://tinyurl.com/6k3d3w7>

24. DAVIS SB "The chemistry of colour removal: a processing perspective" <www.sasta.co.za/wp-content/uploads/proceedings/2000s/2001_davis_THE%20CHEMISTRY%200F%20COLOUR%20REMOVAL.pdf>

25. GWEHENBERGER G. and NARODOSLAWSKY M., 2007 "The ecological impact of the sugar sector- Aspects of the change of a key industrial sector in Europe" <http://www.nt.ntnu.no/users/skoge/prost/proceedings/escape17/papers/T5-88.pdf>

26. MOOSAVI-NASAB M., PASHANGEH S. and RAFSANJANI M, 2010 "Effect of Fermentation Time on Xanthan Gum Production from Sugar Beet Molasses" by <http://www.waset.org/journals/waset/v68/v68-210.pdf>

27. OLBRICH H., 1963 "The Molasses" (Fermentation Technologist, Institut fur Zuckerindustrie, Berlin, Germany), <http://www.btkempe.de/Molasses_OLBRICH.pdf>

28. THOMPSON MC "Softening of clear juice" <www.sasta.co.za/wp-content/uploads/proceedings/1990s/1994-Thompson-Softening%200f%20Clear%20Juice.pdf>

VIII. Appendix

Legislations

1 Metody zkouseni cukrovarskych vyrobku – Stanoveni sacharozy polarizaci

Nahrazeni predchozich norem

Touto normou se nahrazuje CSN 56 0160-5 z 10.11.1986

2 Metody zkouseni tekutych cukru – Stanoveni susiny refraktometricky

Nahrazeni predchozich norem

Touto normou se nahrazuje CSN 56 0161-2 z unora 1995

3 Metody zkouseni cukrovarskych vyrobku – Stanoveni ztraty hmotnosti susenim

Nahrazeni predchozich norem

Touto normou se nahrazuje CSN 56 0160-2 z 1986-11-10

4 Metody zkouseni cukrovarskych vyrobku – Stanoveni granulometrickeho slozeni

Touto normou se nahrazuje CSN 56 0160 z 1971-10-12 cl. 36

5 Metody zkouseni cukrovarskych vyrobku – Stanoveni popela

Touto normou se nahrazuje CSN 56 0160 z 1971-10-12 cl. 44

6 Metody zkouseni cukrovarskych vyrobku – Stanoveni pH potenciometricky

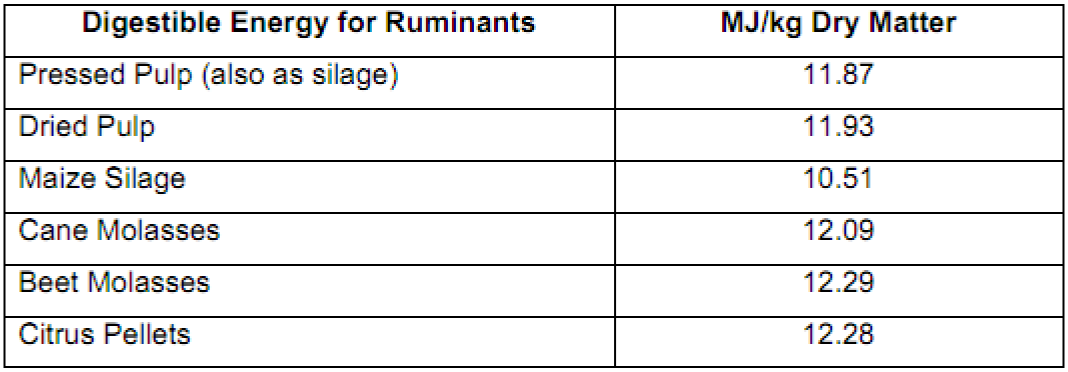
CSN 56 0160 4.cast

7 MELASA Norma jakosti

Nahrazuje CSN 56 5840 ze 4-4-1952

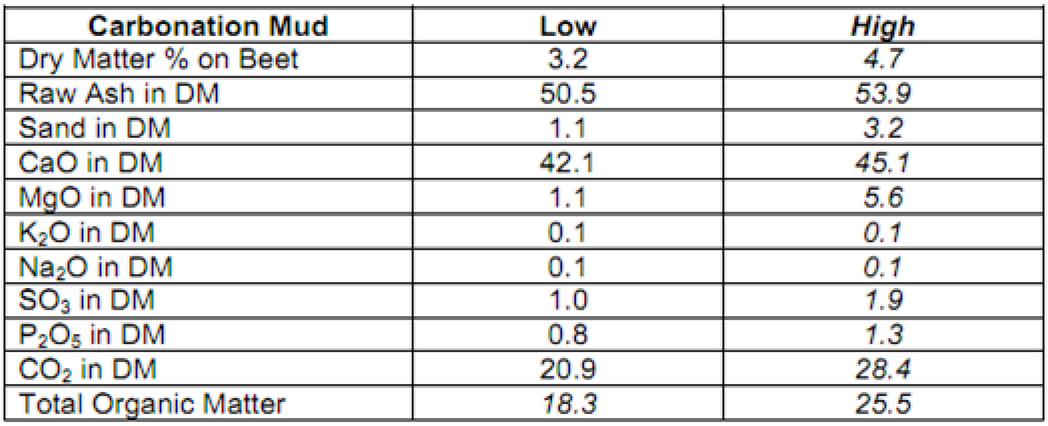
By products of sugar beet industry

Table 1 Digestible energy of some feeds



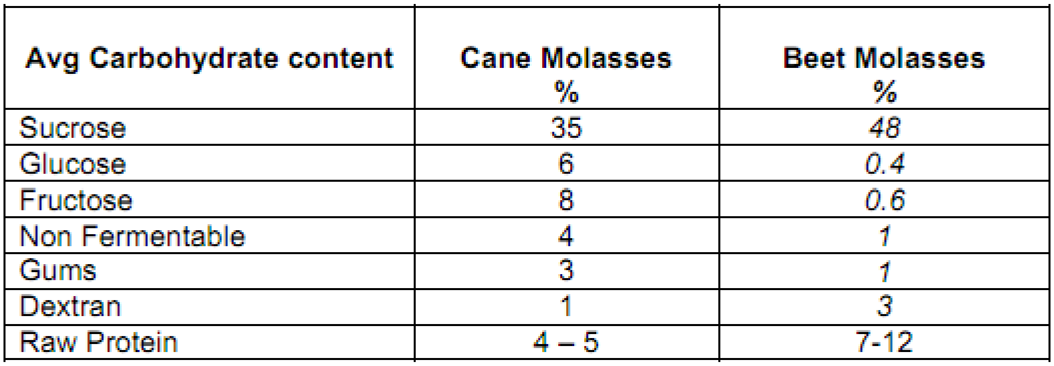
Digestible Energy for Ruminants	**MJ/kg Dry Matter**
Pressed Pulp (also as silage)	11.87
Dried Pulp	11.93
Maize Silage	10.51
Cane Molasses	12.09
Beet Molasses	12.29
Citrus Pellets	12.28

Table 2 Carbonation Mud



Carbonation Mud	**Low**	***High***
Dry Matter % on Beet	3.2	*4.7*
Raw Ash in DM	50.5	*53.9*
Sand in DM	1.1	*3.2*
CaO in DM	42.1	*45.1*
MgO in DM	1.1	*5.6*
K_2O in DM	0.1	*0.1*
Na_2O in DM	0.1	*0.1*
SO_3 in DM	1.0	*1.9*
P_2O_5 in DM	0.8	*1.3*
CO_2 in DM	20.9	*28.4*
Total Organic Matter	*18.3*	*25.5*

Table 3 Cane and beet molasses

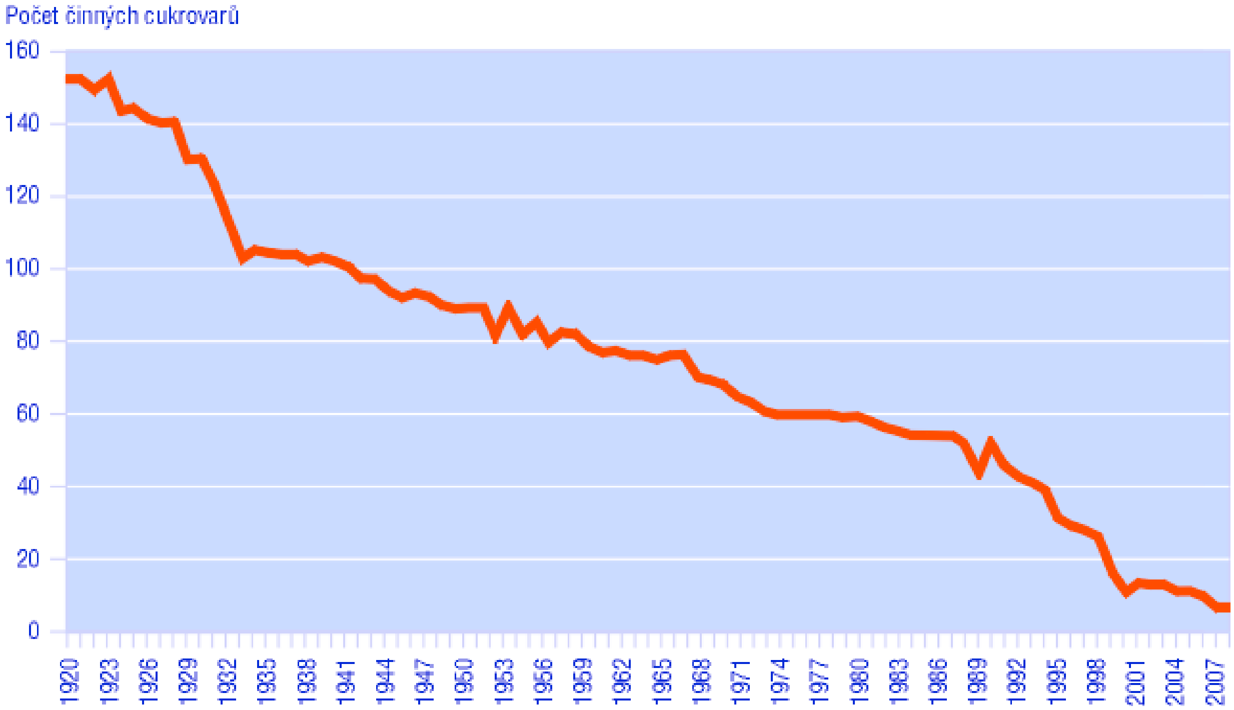


Avg Carbohydrate content	**Cane Molasses %**	**Beet Molasses %**
Sucrose	35	*48*
Glucose	6	*0.4*
Fructose	8	*0.6*
Non Fermentable	4	*1*
Gums	3	*1*
Dextran	1	*3*
Raw Protein	4 – 5	7-12

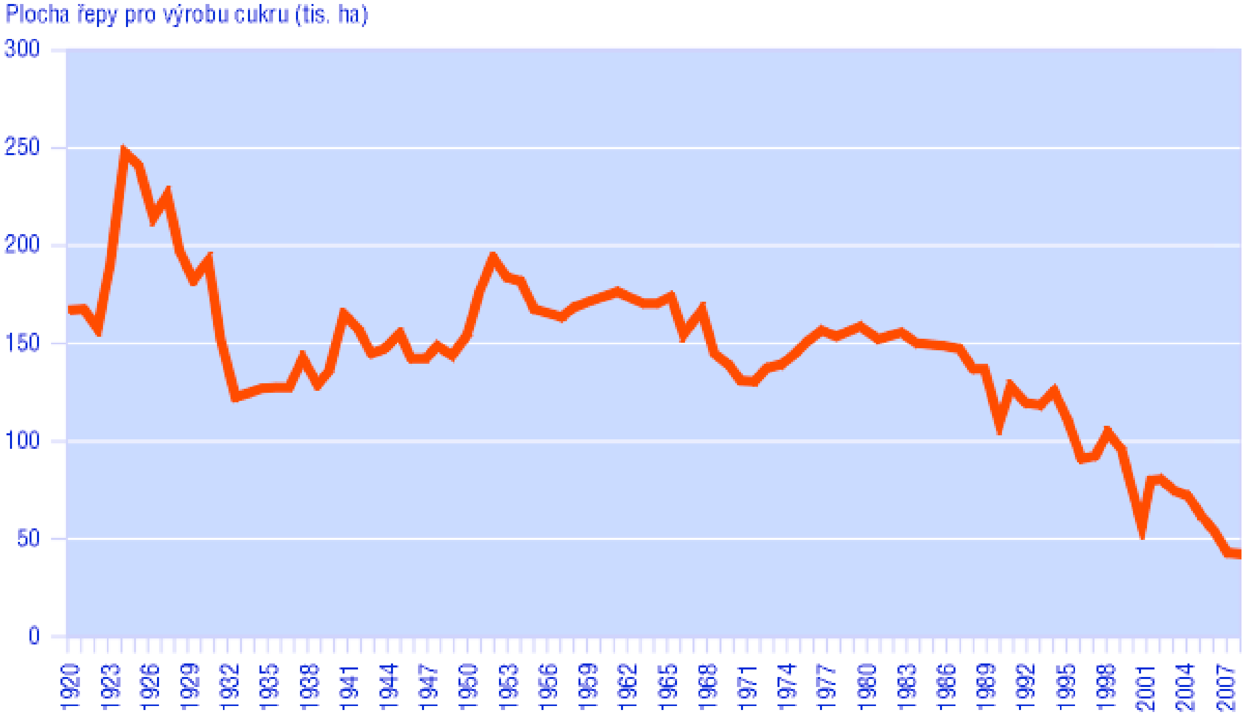
Source: Sugar Technology 1998 Verlag Dr.A.Bartens

Production of sugar beet and sugar in Czech Republic

Graph 1



Graph 2



Sugar factory in Dobrovice

Fig 1 Sugar Dobrovice

Fig 2 Laboratory for analysis, Sugar Dobrovice