Introduction

Sugar beet is currently grown and processed in 18 EU countries and is especially significant for many rural areas. This is due not only to the indispensable contribution of beet growing to the economic welfare of 170,000 farms, but also to the importance of the sugar industry in creating jobs in those regions.

Containing about 75% water, sugar beet is perishable. During the campaign, large quantities of beet (about 100 million tonnes in 2008/09) are transported in order to be processed. Therefore, to reduce the economic and environmental impact of sugar beet transport, sugar factories are traditionally located near the beet fields, in most cases in rural areas.

The EU sugar industry has a long tradition of maximising the use of co-products arising from the beet processing operation, all of which are used in productive applications. In fact, sugar factories are not only suppliers of sugar, but also produce other products, such as animal feed. All parts of the beet are used and converted into valuable products, without waste. These products are for the most part marketed in the region, and thus help bolster the economic strength of EU rural areas.

The following steps take place during sugar beet cultivation and beet sugar production:

**ROTATION CHOICE** – Beet growers usually choose the frequency of beet in their farm’s rotation system according to farm-specific conditions (e.g. soil status, pest and disease prevalence). While growing beet on the same field every four years is a good rule of thumb, most soils are able to sustain one in three year rotations over time without soil quality deterioration and consequent yield loss. One in five and even one in six year rotations also exist.

**VARIETY CHOICE** – Beet growers choose the varieties they wish to grow from a list of approved varieties (i.e. varieties which have passed the required trials). In many cases, this list in turn highlights recommended varieties. These are usually established on a joint basis between growers and processors through the activities of the beet research institutes and seed breeding companies. Apart from the essential criteria for beet variety recommendation, such as root yield and sugar content, other criteria such as early or late maturing, resistance/tolerance to specific pests and/or diseases, nutrient conversion efficiency and internal quality are also evaluated.
SEED ACQUISITION – In general, beet growers order and obtain seed from the sugar factory or other distributors approved by both growers and processors. Most beet seed sown in the EU is pelleted, i.e. the seed is enveloped so as to make it heavier, rounder, smoother and more uniformly-sized, thus facilitating precise mechanical sowing. However, the pellet also contains a small amount of plant protection products (PPPs) which protect the germinating seed and young seedling against early attacks from pests such as pygmy mangold beetles, springtails, symphyllids, aphids, millipedes and wireworms, as well as from diseases such as damping off caused by a fungus (Aphanomyces). Such seed treatment is standard procedure for most seed and eliminates the need for pesticide use straight after emergence.

SEEDBED PREPARATION – This can begin as soon as possible after the harvest of the preceding crop in the rotation. In general, the objectives are to loosen the soil if required, to enhance the breakdown of residues from the previous crop and to avoid proliferation of weeds.

SOWING – Sugar beet is generally sown in spring (mid-March to late April), although there is some autumn-sown (October/November) beet in Spain and Italy. Ideally, beet is sown as early as possible so that the limited growing season can be fully utilised.

PLANT GROWTH AND NUTRITION – From germination of the seed right to the end of its vegetative phase, the plant grows from a 0.03 gram seed to a sugar beet plant with a 1kg root. In order to achieve this 33 000-fold increase in weight (or 7 667-fold increase in dry matter weight), the plant requires sufficiently high temperatures, water and nutrients. Water is principally supplied by rainfall, supplemented by irrigation only when required. Nutrients are provided as much as possible by the soil. They are appropriately supplemented by optimal application of fertiliser according to the nutrients available in the soil and the crop’s nutrient requirements.

PLANT HEALTH – The young plant can be threatened in the first instance by competition from weeds for light, water and nutrients. Furthermore, pests and diseases can severely hamper plant growth and even lead to crop failure. Therefore, apart from selecting appropriately resistant/tolerant varieties and opting for appropriate seed treatments, farmers continuously monitor the crop for signs of stress and are regularly informed about weather conditions likely to favour the development of specific pests and diseases.

PHOTOSYNTHESIS – The plant grows by absorbing the sun’s energy and using it to convert water and carbon dioxide to sucrose. The biochemical process is called photosynthesis, and it uses carbon dioxide which is absorbed from the air. The sucrose is used in the plant to provide the energy for chemical reactions, but in the case of beet, some of it is stored in the root. Thus, the sugar that is extracted in the sugar factory is the natural product of photosynthesis.
BEET HARVEST, STORAGE & TRANSPORT – Seven to eight months after sowing, sugar beet contains around 17% sugar, and is ready to be harvested and processed in sugar factories. Spring-sown beet are generally harvested in autumn and early winter (mid-September to December), although slightly earlier in for example Italy. The period of beet harvesting and processing (campaign) is increasingly extended well into January and even beyond in some cases. Beet harvesting can be round-the-clock work while harvesting conditions are good, particularly if the weather threatens to break and conditions look likely to deteriorate as autumn turns to winter. The beet leaves, which are usually left in the field after harvesting, contain various nutrients which are gradually released into the soil. While some beet is transported directly to the sugar factories, the remainder is stored (for several weeks) in clamps (i.e. heaps) and then transported to the factories to ensure that the raw material is continuously supplied throughout the campaign. Before the factories’ optimum campaign start date can be established, beet yields have to be carefully estimated, and the logistics of the harvesting and beet deliveries to the factory thoroughly planned in order to maximize efficiency. During harvesting, when loading and unloading the beet, care is taken to remove as much soil from the beet as possible using appropriate cleaning machinery - while keeping damage to the beet to a minimum.

BEET PREPARATION – After delivery, the sugar beet (which for the most part are pre-cleaned in the field) are either stored temporarily in the sugar factory’s beet yard or directly transported via conveyor belts or water channels into the beet washing unit. The cleaned beet is cut into strips, known as cossettes.

SUGAR EXTRACTION – The sugar in the cossettes is then extracted. It is diffused out of the cossettes with warm water to form a solution with a sugar concentration of about 15% – the so-called diffusion juice. The exhausted beet cossettes are then pressed and generally dried to produce beet pulp pellets.

JUICE PURIFICATION – Apart from sugar, diffusion juice contains other components (impurities e.g. organic acids, proteins, ...) derived from the crop. These are removed in a purification process involving the use of lime and carbon dioxide. The resultant lime precipitate is filtered. The filtrate is a clear solution of sugar called ‘thin juice’, while the sludge remaining in the filter is pressed to obtain so-called sugar factory lime.

JUICE CONCENTRATION AND EVAPORATION – In the evaporation station, water is removed from the ‘thin juice’ in a series of successive evaporating vessels under vacuum until a syrup with around 70% dry matter is obtained. This so-called ‘thick juice’ is viscous, golden yellow and clear.

CRYSTALLISATION – The ‘thick juice’ is further evaporated and crystallised in specially designed vacuum pans until sugar crystals form (the ‘thick juice’ can also be stored and used for the production of sugar after the beet processing campaign). Sugar crystals are then separated from the accompanying final syrup by centrifugation. This process is carried out two or three times. The centrifuged sugar is dried and stored in silos, before being sieved and packaged according to the highest quality customer standards. The final syrup, which still contains 50% sugar, is known as molasses.
ZERO WASTE: MANY OTHER VALUABLE PRODUCTS AND CO-PRODUCTS

During the washing process, the remaining adhering soil (known as soil tare) is removed, any remaining leaves and stones are separated out and beet tails and roots accumulate. All these co-products are reclaimed for use in many productive applications.

The soil contained in the washing water can be directly returned to the fields or can be stored in settling ponds so that it becomes concentrated to form high quality soil. This is then used for a wide range of applications, including agricultural land improvement, in the sports amenity industry, civil engineering and housing construction, garden centres (horticulture), land reclamation and landfill site restoration.

Stones are used in road building and in the construction industry.

Beet leaves, tails, and roots are re-used as energy-rich and easily-digestible feed for ruminants, or as compost which makes a useful soil conditioner. In certain countries tails and beet parts are also used in rural biogas plants as biomass for co-fermentation.

On average, 50kg (dry matter) of beet pulp are produced per tonne of beet. Beet pulp is a high energy and top quality animal feed, which is used in compound feed products or fed directly. Pulp is generally dried to produce beet pulp pellets. In some cases, notably when there is local demand for fresh animal feed, the factory can provide the more perishable ‘fresh’ pressed pulp. The latter is, most often, the result of pressing the cossettes in order to obtain a product with up to 25% dry matter to be ensiled (stored) by the farmer or to be consumed directly by the animals. In many countries, beet pulp is highly valued by the beet growers, who take it back to their farms during the processing season. In many cases, beet pulp is transported in the otherwise empty beet lorries returning from the factory thus avoiding unnecessary transport. The processing and use of animal feed is subject to strict EU and national feed regulations. Moreover, beet pulp is a raw material with interesting potential for use in applications other than simply animal feed.

For example, beet fibre can also be used for food applications and beet pulp’s biomass can be a substrate for biogas.

Sugar factory lime from the juice purification process is used as a soil conditioning product (fertiliser) for agricultural land. It is marketed in a range of forms to suit various spreading techniques.

Molasses, the remaining syrup from the crystallisation stage of the process (around 50kg per tonne of beet), is used in a wide variety of market applications. These include use as a feedstock by fermentation industries to produce high value pharmaceuticals, citric acid, yeast, ethanol (for various uses, such as fuel and beverages) and specialist biochemicals. However, the largest single application is as a supplement for animal feed, where it can either be sold to feed manufacturers or farmers (e.g. to add to grass or maize silage to improve product quality), or can be added directly to animal feed at the sugar factory. The sweet taste and relatively high energy content make molasses a highly appreciated raw material for the producers of mixed feeds. Molasses is used in both energy feed and mineral feed for virtually all types of farm animals. Of particular importance is the high digestibility of its organic ingredients.

BIOGAS: The production of biogas by fermenting the waste water during the anaerobic water treatment process in the sugar factory makes an environmentally-friendly and sustainable contribution to reducing fossil fuel. This biogas, which has a methane content of around 75%, helps reduce fossil fuel demand (to produce heat and electricity). Biogas is increasingly used in the sugar industry as a valuable substitute for fossil fuels, for example, as a source of energy in the boiler house (the factory’s power station) or for drying the pulp. In some countries, beet tails and other parts are used in rural biogas plants as biomass for co-fermentation. In other cases, where pulp is not used as cattle feed, it can be used to produce biogas.

HEAT AND ELECTRICITY: The surplus heat generated from the sugar factories’ combined heat and power systems can be re-used in the evaporation stages and also to heat the sugar juice throughout the process. The remaining heat can be exported and sold to neighbouring consumers in the form of hot water or steam. In the same manner, where more electricity is generated than required, it is exported to the grid or sold to the electricity supply companies.
BIOETHANOL: The raw juice, the ‘thin juice’ and the ‘thick juice’ correspond to different processing steps which correlate to an increase in the concentration of sugar content. These intermediate products can be used directly to manufacture bioethanol through a fermentation process. Molasses resulting from sugar beet processing can also be used to produce bioethanol. Sugar companies in many EU countries have invested in the production of bioethanol, which can then be used for various purposes, mainly for fuel and for beverages. Vinasse, a co-product resulting from the production of bioethanol or yeast from beet (around 40kg of dry matter per tonne of beet), can be used as animal feed or as a fertiliser due to its high mineral and high organic matter content, which is ideally suited for soil conservation. Vinasse can also be returned to the distillation and fermentation processes as a raw material.

The impact of REACH on the sugar industry’s zero-waste objective

REACH is a new European Community Regulation on chemicals and their safe use (EC 1907/2006). It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances. The new law entered into force on 1 June 2007.

The aim of REACH is to improve the protection of human health and the environment through better and earlier identification of the intrinsic properties of chemical substances. At the same time, the innovative capability and competitiveness of the EU chemical industry should be enhanced. One of the fundamental changes brought about by REACH was the change of responsibility from public authorities to industry in demonstrating the safe manufacture and use of chemicals.

REACH legislation is mainly directed at the chemical industry. However, its far-reaching scope means that many substances used or produced by non-chemical sectors such as the food and drink sector are also affected. These include a number of co-products necessary to or derived from sugar production. The European sugar industry aims to be a zero-waste industry by maximising the value of all its products and co-products. It is therefore important that the application of the new REACH rules takes due account of the sugar industry’s specific situation so as not to jeopardise the achievement of the zero-waste objective.

The financial aspects of REACH are not to be neglected either. The costs related to the registration of substances, including all the costs associated with the setting up of a Consortium to deal with the necessary tests of a substance under REACH can often exceed €1 million per substance. In some cases, it is only the amount of the substance which is marketed for non-food and non-feed uses that falls under REACH. This may lead some companies to stop marketing that substance for REACH-relevant uses in order to avoid the associated registration costs. This may put pressure on some companies to conclude that it is better for a product to be considered as waste and dealt with under the relevant regulations for the disposal of waste.

REACH will therefore be one of the main focuses among the environmental issues of concern for the sugar industry in the years to come.