Waste Management 48 (2016) 95–105

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Technical assessment of processing plants as exemplified by the sorting of beverage cartons from lightweight packaging wastes

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ARTICLE INFO

Article history:
Received 21 August 2015
Revised 21 October 2015
Accepted 22 October 2015
Available online 4 November 2015

Keywords:
Lightweight packaging waste processing plant
Beverage carton
Sample taking
Technical assessment

ABSTRACT

The recovery of beverage cartons (BC) in three lightweight packaging waste processing plants (LP) was analyzed with different input materials and input masses in the area of 21–50 Mg. The data was generated by gravimetric determination of the sorting products, sampling and sorting analysis. Since the particle size of beverage cartons is larger than 120 mm, a modified sampling plan was implemented and targeted multiple sampling (3–11 individual samplings) and a total sample size of respectively 1200 l (ca. 60 kg) for the BC-products and of about 2400 l (ca. 120 kg) for material-heterogeneous mixed plastics (MP) and sorting residue products. The results infer that the quantification of the beverage carton yield in the process, i.e., by including all product-containing material streams, can be specified only with considerable fluctuation ranges. Consequently, the total assessment, regarding all product streams, is rather qualitative than quantitative. Irregular operation conditions as well as unfavorable sampling conditions and capacity overloads are likely causes for high confidence intervals. From the results of the current study, recommendations can basically be derived for a better sampling in LP-processing plants. Despite of the suboptimal statistical results, the results indicate very clear that the plants show definite optimisation potentials with regard to the yield of beverage cartons as well as the required product purity. Due to the test character of the sorting trials the plant parameterization was not ideal for this sorting task and consequently the results should be interpreted with care.

1. Introduction

Due to their huge potential as a resource of metals, paper, cardboard, cartons as well as plastics, post-consumer packaging wastes are subjected to recycling obligations with specific quotas as legally stipulated by national guidelines. Even so, there are national differences in the materials targeted for recycling due to lacking harmonization of European (EU, 2013) and national regulations. Unlike many other EU countries, the jurisdiction of the Packaging Ordinance in Germany (Verpackungsverordnung/VerpackV, 2014) also extends to composite packaging consisting of several substance groups and whose mass fraction of main components lies at <95 wt.%. This includes, for example, packaging metals (beverage cans) but also beverage cartons. According to the DKR (German Society for Recycling and Raw Materials)/DSD specifications which define the material recycling requirements in Germany, beverage cartons are "used, empty, system-compatible consumer packaging of carton composite materials consisting of carton/polyethylene (PE) or carton/aluminium/PE for the filling of liquid and pasty products such as milk-, juice- and ready-made sauce cartons including by-components such as caps etc." (DKR, 2012).

The recycling of post-consumer packaging materials is intended to replace primary raw materials. In order to accomplish this, these secondary raw materials should have a sufficiently high quality. For a marketable beverage carton product, for example, the purity according to the DKR/DSD specifications needs to be >90 wt.%; this means that less than 10 wt.% foreign materials are tolerated. Moreover, the permissible composition of these foreign materials is subjected to defined specifications.

For the recovery of secondary raw materials, the product requirements necessitate technological treatment measures whose type and extent are mainly determined by the origin of the waste to be sorted. If lightweight packaging wastes have already been separately collected by, e.g. the "Duale Systeme" in Germany, pre-concentrates in LP-processing plants are generated according to the required product specifications. These are subsequently processed to secondary raw material in mechanical recycling facilities. Thus, for example, fibre materials for the paper industry are produced from beverage cartons in the wet processing plant.

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http://dx.doi.org/10.1016/j.wasman.2015.10.023

In order to make the treatment process as efficient as possible, the plant operator has to know the possibilities and limitations of the respective plant design and parameterization. Hereby, the current state, as determined by the corresponding data generation, ought to deliver data on the produced product qualities and masses as well as possible information on plant optimisation potentials, e.g. by quantifying loss yields of valuable materials. Despite the importance of generating sampling-based data to evaluate LP-processing plants, the published state of knowledge is very limited. Available information on the theme is mostly restricted to general data on recovery targets (Christiani, 2009). There are no known publications about the methods of data generation or on the related specific challenges regarding the sampling of LP-processing plants. Even if they do exist, the acquired values of the sorting results cannot be objectively evaluated because they are either confidential, spotty or are compromised by special interests.

Thus, currently an objective method for the assessment of postconsumer packaging processing plants is lacking. Recently in the Netherlands controversial claims have been made by LP processing plant operators regarding the total percentage of all recyclable materials that can be obtained from a mixed LP input. Claims that this sorting yield can exceed 90% by one sorting plant operator has resulted in court cases with competitors (Court case KG ZA 14-984). On top of that, the Dutch monitoring authority Nedvang also evaluates LP processing facilities on hand of the mass of all valuable recyclable materials (polyethylene terephthalate (PET), PE, polypropylene (PP), films and optionally also metals and BC). The relevant quotient calculated from the ratio of the aforementioned sorted products made to the sum of the aforementioned fractions plus MP should exceed 45 wt.%. Nedvang ensures in this manner that the loss of valuable materials into the MP fractions is minimized.

2. Background

2.1. Technological aspects

Processing plants for postconsumer LP waste are engineered to produce standardized sorting products from various input streams such as separately collected LP and mechanically recovered LP. Although, the sorting catalogue (list of intended products) and the composition of the input stream varies between countries and regions, these plants do have a similar configuration of separation machines (aggregates). The parameterization of the process steps (e.g. evaluation algorithm sensor-based sorting, air velocity of the air classifier, screen mesh size etc.) is adjusted to the specific processing task.

Despite the individual differences, the overall process design of LP-processing plants are similar to one another The LP-waste is separated into reusable material fractions by exploiting the various article properties that are characteristic for the respective substance group and which can be accordingly used as a separation criterion, such as, e.g., magnetic properties, (e.g. tinplate), particle shape (e.g. bottles, films), particle size (fines), optical properties (e.g. near infrared (NIR)-spectra of the polymers) as well as substance densities (e.g. separation of films and metals). In particular, the separation of types of plastics has been decisively improved through the developments of sensor-based technology in recent years. Regardless of its limited capacities and considerable costs, however, manual sorting is still important for quality control.

Corresponding maximum criteria that ensure a loss-free recovery of the valuable materials into the respective sorting products by simultaneous maximum purity are not feasible for technological reasons.

It is well known that technical separation processes show finite efficiencies; this means that they do not separate precisely, which would be ideal. Thus, either valuable materials are discharged into other sorting products or foreign materials are introduced into recycled products. Whereas the first case of a missing yield leads to a loss of valuable materials, in the latter case the entry of foreign materials into these products reduces the quality of these recyclable products on the one hand, but increases its mass and quantity on the other hand. There are numerous reasons for the corresponding lost yields and these may be attributed to substance properties of the material to be treated, plant configuration as well as to process control.

2.2. Technological assessment of LP-plants

Detailed knowledge of the quantity and quality of the generated sorted products is a crucial prerequisite for ensuring a technically cost-effective plant operation. A technological assessment helps to describe the performance of the LP processing plant and can help to optimise the plant processes. Additionally, these assessments are relevant for economic and environmental scientists that want to study recycling processes.

Such a comprehensive plant assessment requires the gravimetric determination of all output streams, the sampling of the generated sorting products and their compositional analysis.

Potential sources of sampling errors will have to be prevented, which translate into a large effort in terms of logistics, personnel and, thus, financial costs for carrying out the sampling. The total sampling error is caused by errors incurred through sampling, sample preparation as well as sample analysis (Rasemann, 2005). In particular, the typically very heterogeneous composition of waste mixtures poses enormous challenges during sampling (Pehlken et al., 2005).

The key requirement for an error-reduced sampling is to representatively determine the material properties to be investigated. The necessary effort to do this mainly depends on the population size and the upper limit of the particle size distribution. However, there are no direct guidelines for sampling LP from processing plants. In Germany, the sampling is typically based upon the guideline LAGA PN 98.

Mainly through the number of the individual samples to be drawn, the sampling effort generally increases with increasing population size. Thus, according to LAGA PN 98, for example, at least eight individual samples have to be taken of a sorted product with a total volume of 30 m^3, while 12 and 16 single samples need to be taken of sorted products with total volumes of 60 m^3 and 100 m^3, respectively.

For ascertaining the volume of the individual samples that has to be taken from a sorted product, the mass as well as the bulk density of the sorted product both need to be known. These values are usually not known for the sorted product that has to be sampled and often values derived from previous experiments are used. Especially for LP-wastes, however, considerable fluctuation margins may occur for the bulk density: Already for the same articles, the bulk density is considerably influenced by the delivery form (pressed or loose), the type and extent of mechanical stress in the process (e.g. by compression during the intermediate storage in the feeding hopper) or by the degree of soiling of the articles. Thus, regarding beverage cartons, for example, the bulk density can clearly vary depending on the filling level of residual contents as well as on the deformation of the cartons: According to the bulk density measurements, which were determined as part of the underlying study (Thoden van Velzen et al., 2013b), beverage cartons have bulk densities of 25–60 kg/m^3 as loose, freshly collected material. In one case, this material was compressed into a bale and the density rose to a value of 210 kg/m^3. This means that the bulk