COMPARISON OF LIFE CYCLE ASSESSMENT FOR DIFFERENT VOLUME POLYPROPYLENE JARS

Nevena M. Krkić*, Vera L. Lazić and Danijela Z. Šuput

University of Novi Sad, Faculty of Technology, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia

When deciding what packaging is the most appropriate for a product there are many factors to be considered. One of them is the impact of the packaging on environment. In this work, life cycle inventory and life cycle assessment of two different volume packagings were compared. The data were collected on the types and amounts of materials and energy consumption in the process of packaging and distribution of hand cream packed in polypropylene jars of 200 and 350 mL. Life cycle inventory (LCI) and life cycle impact assessment (LCA) were calculated. It was found that the total mass flow was higher for the jars of 350 mL. After analyzing individual flows, it was found that in both cycles (polypropylene jars of 200 and 350 mL),the consumption of fresh water was a dominant flow. This fresh water flow is mostly (95%) consumed in the injection molding process of manufacturing jars from polypropylene granules. The LCA analysis showed no significant difference in global warming potential between different volume jars. The process that mostly affected global warming was the production of polypropylene jars from polypropylene granules by injection molding for both jar volumes. Judging by the global warming potential, there is no difference of the environmental impact between investigated jars, but considering the mass flow and water consumption, more environmental friendly were the 200 mL jars.

KEY WORDS: Life cycle assessment, polypropylene, jars, packaging

INTRODUCTION

Through its entire life cycle the packaging significantly affects the environment. The environmental impact begins with the exploitation of the raw materials for packaging production, continues through the packaging process, and ends when the packaging appears as the packaging waste, after the utilization of the packaged product. Depending on the type of packaging, raw materials production and production of the packaging itself have a major impact on the environment, as they affect the ratio of natural resources. In addition, these processes consume some amount of energy, which also has effect on the environment. The process of packing, depending on the type of product and type of

---

* Corresponding author: Nevena M. Krkić, University of Novi Sad, Faculty of Technology, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia, e-mail: nevena.krkic@uns.ac.rs

packaging, can also have a significant impact on the environment, and this aspect should be taken into account when choosing packaging. The packaging process should be mana- ged properly to ensure the percentage of scrap is minimal (1, 2).

After using the product, its packaging emerges as packaging waste in landfills where it shows a negative effect on the waterways, land and pollutes the air. Industrialization, high technology and consumer demand for safe products lead to the problem of large quantities of used, discarded packaging (3). The life cycle of packaging includes all of these phases, starting from the raw materials production and delivery, packaging material production, packaging preform formation and processing, delivery of the packaging material or packaging, packaging formation, filling and closing, storage, distribution and delivery to retail and in the end of the cycle, processes of separation, recycling and disposal (4).

Environmental friendly or eco-friendly is the packaging that uses less energy and ma- kes less pollution during the production, application and removal than other materials with the same purpose. For the purpose of easier separation of packaging materials for recycling, universal labels have been introduced to indicate the consumer that the packa- ging material is recyclable, and should be separated for recycling (5). In order to consider the life cycle impacts on the environment, a relatively new method, called the product (packaging) life cycle assessment (LCA), was developed. It is the only standardized method that is currently used to assess the product (packaging) life cycle. The goal, the motivation for the research, must be clearly defined from the very beginning, because it may later affect the certain phases of the life cycle. In the case of packaging, the analysis begins with the process of raw materials extraction from the environment, continues in the production, product consumption and ends when the packaging or its derivatives enter the waste streams. Operations such as transport, recycling, maintenance must be conside- red in the analysis (6). Assessing the product life cycle includes life cycle inventory for- ming and assessment.

Evaluation of packaging life cycle includes the analysis of the packaging along with the evaluation of life cycle inventory. Life cycle assessment is equivalent to ecological balance and environmental profiles (7).

Apart from the possibility of packaging life cycle assessment, this method allows a comparison of similar packagings, which makes it even more important. This comparison is possible between the systems of similar packaging, such as the original packaging and reduced weight packaging. In such cases, life-cycle assessment is used to confirm intuiti- on, but also to quantify the effects of such changes. Sometimes, however, the same pro- duct can be packaged in containers that can be drastically different. Life cycle assessment can be used to compare the overall environmental burden, despite the many differences between the packaging systems, although it is necessary to take particular care when in- terpreting such comparisons (8).

The aim of this paper was to assess and compare the life cycle impact of two con- tainers of different volume made of polypropylene (PP), which are used for packaging of pharmaceutical products.

EXPERIMENTAL

Packaging process scheme forming

The process of packaging chamomile and olive oil hand cream in PP jars of 200 mL and 350 mL was recorded at the factory for production of cosmetics and chemical products („Yuco-hemija" DOO, Bački Jarak, Serbia). The process of packaging was followed through the liner filler, which is composed of volumetric filler, aluminum foil sealing equipment, labeling and closing machine.

The supplier of the PP jars of 200 mL was the company from Subotica, Serbia, while the supplier of PP jars of 350 mL was from Nova Pazova, Serbia. The empty jars are delivered in bags, 300 pieces per bag of 200 mL and 200 pieces per bag of 350 mL. The user stores the empty jars for a period of 2 to 3 months.

The PP jars were disinfected with alcohol before printing, then placed on the conveyor belt, which is connected to the printer, where the date and expiry date are set to be printed.

Cream filling in the PP jars is made on the linear filler. Filling the PP jars, previously placed on the conveyor belt, is done with two dozers that allow precise cream dosage. The weight of the cream to be filled into the jars is adjusted. Based on the known volume and density of the cream, the mass is determined, which may deviate ±2%, in accordance with the specification. The speed of the PP jars filling for 350 mL is 10 pieces/min and for the 200 mL jars, 16 pieces/min.

After completing the filling process, sealing with aluminum foil (Al foil) is carried out. The supplier of the aluminum foils is from Subotica, Serbia. Sealing is done on the part of the linear filler, sealer. The heater is used to adjust the operating temperature and sealing time, which is defined based on packaging formats. The operating temperature and time are set via the appropriate clip. The sealer can operate manually or automatically, which is regulated with the aid of a button on the device itself.

After sealing, the PP jars are labeled. The device for labeling consists of the conveyer belt, a wheel that sets the width and height of the containers that are labeled and label carrier. A wheel is used to set the width and height of the jars and the jars are then manually placed on the conveyor belt and the carrier sticks the label to the jar. The labeling machine is automatic, with manual placing of the jars on the conveyor belt.

In the end of the filling process, the PP jars are closed. The closing unit consists of the clips for setting jar width, according to which appropriate closure and closing tool is selected. A photocell regulates the unit operation. For small amount of packed products, the closing process can be performed manually.

Individual packaging is put into the transport boxes made of corrugated cardboard. The supplier of transport boxes is from Novi Sad, Serbia. The transport boxes are formed by gluing. A package contains 24 pieces of 350 mL jars, or 48 pieces of 200 mL jars. The transport boxes dimensions are: 380x290x235 mm, for 200 mL jars and 420x320x140 mm, for 350 mL jars. The transport boxes are placed on wooden pallets that are stored in the warehouse.

The factory delivers products up to 1,000 km distance. The greatest distance is up to Nis, where during the final product delivery raw materials and packaging is supplied. The

product transport is carried out by trucks and vans, which consume Euro diesel. The vans ("Kango" and "Cleo") are used for short distance transport for economical reasons.

Collecting relevant data (inputs and outputs)

The software system used, GABI 4, requires information about most important machine characteristics and preprocessing of the collected data.

Further, the software used requires defining of the following parameters:

- Functional unit - represents the amount of cream sales per year for the two largest consumers ("Mercator group" and "Delta Maxi"), from Belgrade, Serbia. Functional unit was calculated based on the sales in February and December 2010.
- Reference flow - number of PP jars that will be required for the amount of cream defined by functional unit to be delivered to the customer. For the 350 mL jar, this number is 1824 pieces, and for the 200 mL jar, 3192 pieces.
- Product system - product system with the system boundaries (Fig. 1).

Figure 1. Life cycle scheme for PP jars of 350 mL (with asterisk) and 200 mL (unmarked)

* In Fig. 1, the numbers marked with an asterisk represent data regarding all life cycle stages for 350 mL jars and unmarked numbers for 200 mL jars.

All necessary data for lifecycle steps: printing, filling, sealing, closing, labeling, over packing, transport, distribution, sale and cream consumption for PP jars of 200 mL and 350 mL was collected at the factory ("Yuco hemija" from Bački Jarak, Serbia) (Fig. 1). For life cycle steps: PP jars production by injection molding, transport boxes production, Al foil production and disposal of used jars the data were used from the software program GABI 4. A 100% of landfill disposal was assumed for used PP jars.

RESULTS AND DISCUSSION

Life cycle inventory

After entering all the data shown in Fig. 1, using software GABI 4, life cycle inventory for PP jars was calculated (total mass of all input and output flows for the system, i.e. input and output) and it is shown in Fig. 2.
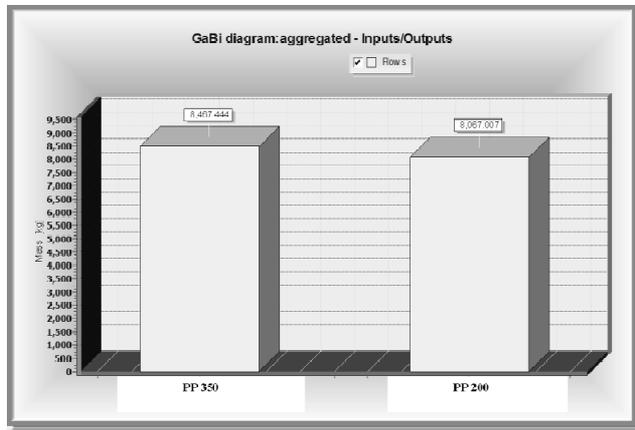
Figure 2. Life cycle inventory for PP jars with different volume (350 mL and 200 mL)

The sum of all input and output flows is lower for 200 mL PP jars (PP 200): 8067.00 kg, compared to 350 mL PP jars (PP 350): 8467.44 kg. After analyzing the material and energy flows within the system (Fig. 1), it can be seen that there is different material and energy consumption for the cycles of PP jars of different volumes. This leads to different total mass inventory. One of the reasons is significantly lower mass of the PP 200: 31.3 ± 2 g, compared to PP 350: 58.8 ± 2 g. Although it requires fewer PP 350 pieces: 1824, compared to 3192 pieces of PP 200 to deliver the same amount of cream to the consumer, the PP material usage is still higher for PP 350 (107.25 kg) than for PP 200 (99.91 kg). Therefore, the amount of waste PP that gets to the landfill after cream consumption is higher for PP 350. The mass of aluminum foil for sealing jars after filling is lower for PP 350 (2.49 kg), compared to the PP 200 (3.24 kg). The corrugated cardboard masses used for transport packaging were: 22.68 kg for PP 350 and 9.05 kg for PP 200 (Fig. 1).

Analyzing the weak points of the system („weak point analysis" function of GABI 4) and breaking down the total inventory to individual flows, it has been found that the dominant flow is fresh water consumption, followed by the emissions into the air: CO_2, steam and exhaust gases, as shown in Fig. 3.
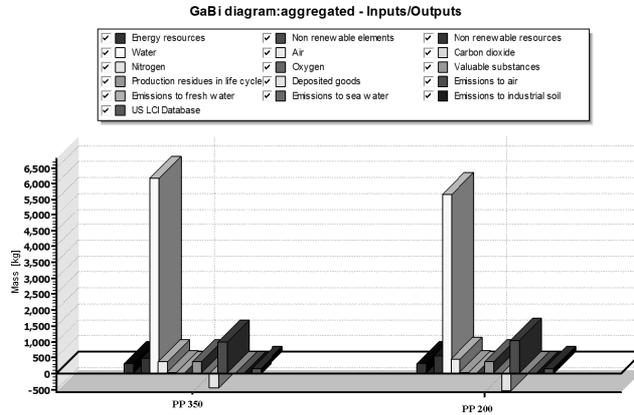

Figure 3. Life cycle inventory of PP 350 and PP 200 mL, individual flows of materials and energy

The system weak point analysis showed that the injection molding process of the production of PP jars from PP granules has the highest degree of contribution to the overall life cycle inventory (Figs. 3 and 4). The two most important items in the life cycle inventory of PP jars, fresh water consumption and emissions to air originate mainly from the process of PP jars injection molding (Fig. 4).
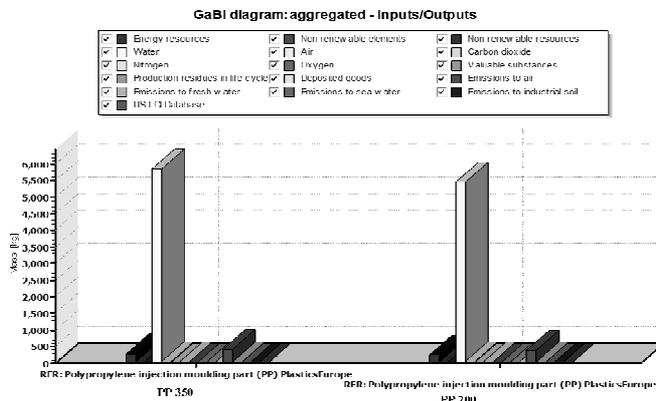

Figure 4. Inventory of the PP jars injection molding process

The total water consumption in the life cycle of PP 350 was 6167.0 kg, of which 5856.7 kg or 95% was spent in the process of injection molding. Similarly, the total water

consumption in the life cycle of PP 200 was 5668.4 kg, and for the production of jars by
injection molding 5455.8 kg or 96%.

   Total emissions in the PP 350 life cycle is 968.7 kg and during the molding process
419.7 kg or 43% is emitted. In the PP 200 life cycle, of a total 1036.8 kg emitted, the
molding process makes up about 391.0 kg or 38%.

PP jars life cycle assessment (LCA)

   Appropriate tools were used to calculate the life cycle assessment (LCA) on global
warming, calculated as equivalent kg of CO_2. It was observed that the impact of PP 350
life cycle is slightly higher (Fig. 5). For the PP 350 global warming potential was 563.1
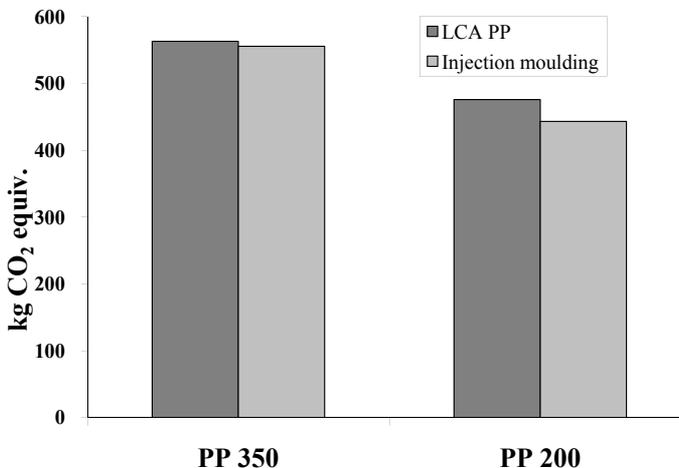kg CO_{2equiv} and for PP 200, 555.5 kg CO_{2eqiv}.

Figure 5. Life cycle assessment on global warming potential (kg $CO_{2\ equiv}$) and
contribution of injection molding (kg $CO_{2\ equiv}$) process for different volume PP jars

   The LCA and system weak point analysis allowed us to single out process that mostly
affected global warming. This process is the production of PP jars from PP granules by
injection molding (Fig. 5). Of the total PP 350 LCA on global warming, only the injec-
tion molding process produces 475.9 kg or 85% of CO_{2eqiv}. For the PP 200, the injection-
molding process makes up 443.3 kg CO_{2eqiv} or 80% of the total life cycle CO_{2eqiv} produc-
tion.

   The relevant data for the PP jars injection molding, manufacturing of cardboard trans-
port packaging and production of aluminum foil were taken from the software. This data
refer to the characteristics of these processes in the EU (especially Germany). It would be
useful to continue the research and collect data for these processes in our country. With
these data collected, a more comprehensive analysis of the LCA could be given, as well
as possible improvement measures at the most sensitive points of the system. For exam-
ple, the PP jars lightweightning (material saving), recycling of discarded jars, injection
molding process optimization.

CONCLUSION

Comparing environmental impacts of cream jars of different volume, it was found that the usage of the larger volume packaging did not bring about a reduction in life cycle inventory, as well as it did not reduce packaging impact on the environment. The life cycle assessment of global warming potential showed only a slight difference between different volume jars, but the life cycle inventory was considerably lower for the 200 mL jars. This is partly due to the fact that the mass of a 350 mL PP jar is two times greater than that of 200 mL jar, requiring thus a larger amount of the material to distribute the same amount of cream to the consumer. Highest contribution to the life cycle inventories (70 % or more) showed the production process of PP jars by injection molding.

Acknowledgement

REFERENCES

1. Dean, D.A.: Plastics-an Introduction, in Pharmaceutical Packaging Tehnology. Eds. Dean, D.A., Evans, E.R. and Hall, I.H., Taylor and Francis, London (2000) pp. 264-326.
2. Lazić, V. and Novaković, D.: Ambalaža i životna sredina, Faculty of Technology, Novi Sad (2010) p. 122.
3. Lazić, V., Krkić, N., Gvozdenović, J. and Novaković, D.: Packaging Life Cycle Assessment. Journal on Processing and Energy in Agriculture. **14**, 1 (2010) 61-64.
4. Kirwan, M.J. and Strawbridge, J.W.: Plastics in Food Packaging, in Food Packaging Technology. Eds. Coles, R., McDowell, D. and Kirwan, M.J., Blackwell Publishing, San Francisco (2003) pp. 233-237.
5. Lazić, V., Gvozdenović, J. and Popović, S.: Packing Between the Need and Environmental Problems. Journal on Processing and Energy in Agriculture. **13**, 3 (2009) 226-228.
6. Robertson, L.G.: Food Packaging Principles and Practice, Massey University, Palmerton North (2006) p. 518.
7. Huang, C.C. and Ma, H.W.: A Multidimensional Environmental Evaluation of Packaging Materials. Sci. Total Environ. **324**, 1-2 (2004) 161-172.
8. Sonnemann, G., Castells, F. and Schuhmacher, M.: Integrated Life Cycle and Risk Assessment for Industrial Processes, Lewis Publishers, Boca Raton (2004) p. 40.

ПОРЕЂЕЊЕ УТИЦАЈА ЖИВОТНИХ ЦИКЛУСА ПОЛИПРОПИЛЕНСКИХ КУТИЈИЦА РАЗЛИЧИТИХ ЗАПРЕМИНА НА ЖИВОТНУ СРЕДИНУ

Невена М. Кркић, Вера Л. Лазић и Данијела З. Шупут

Универзитет у Новом Саду, Технолошки факултет, Булевар цара Лазара 1, 21000 Нови Сад, Србија

При одабиру амбалаже балансира се између технолошког, економског, маркетиншког и еколошког оптимума. Све ове захтеве потребно је задовољити у што већој мери. Чест је случај да се економски и еколошки најоправданија решења поклапају. У овом раду је, са еколошког становишта, анализирана оправданост употребе амбалаже веће запремине, уз примену софтвера за процену утицаја животног циклуса.

Сакупљени су подаци о врстама и потрошњи материјала и енергије у процесу паковања и дистрибуције једног типа креме за руке, који су унесени у софтвер за израчунавање инвентара животног циклуса и процену утицаја животног циклуса на околину. Уочено је да је укупни инвентар маса већи за циклус полипропиленских кутијица од 350 mL, у односу на кутијице од 200 mL. Разлагањем инвентара на поједине токове и након анализе слабих тачака система уочено је да у оба циклуса (полипропиленске кутијице од 200 и 350 mL) доминира потрошња свеже воде, која се највећим делом (око 95%) троши у поступку производње кутијица бризгањем из гранулата полипропилена. Поређењем поступка бризгања, уочено је да је инвентар за овај процес, као и потрошња свеже воде, мања код бризгања кутијица од 200 mL. Аналогно инвентару животног циклуса, утицај животног циклуса амбалаже за паковање креме за руке на глобално загревање већи је за циклус кутијица од 350 mL.

Резултати овог рада су показали да је у анализираном случају еколошки прихватљивија амбалажа мање запремине. Да би се даље утицало на смањење утицаја амбалаже на животну средину потребно је радити на уштеди материјала и производњи полипропиленских кутијица мање масе, увести рециклирање материјала одбачених кутијица и радити на оптимизацији процеса производње кутијица методом бризгања.

Кључне речи: животни циклус, утицај, полипропилен, кутијице