The Quality, Benefits and Differentiation of Aluminium Single Serve Portion Capsules for Drinks

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Abstract

Aluminium capsules can be used as the final packaging for any type of powdered foods, such as tea or vitamin and similar hot drinks. Aluminium represents a 100% barrier, is impermeable, extends the shelf life of the final product, is recyclable and an alternative to plastic. A wide range of individualized products, including the capsule as attractive single-use possibility, made it possible to satisfy the preferences and expectations of consumers.

Currently two main materials for single serve portion coffee capsules are in use: aluminium and/or plastic based.

Key words: Aluminium, lacquering, printing

1 INTRODUCTION

Aluminium capsules open up a whole new array of options for enhancing the visual features of a product, whether embossed or printed, with or without logos or brand names. This also allows for the individualisation and recognition of a particular product, because the application of a desired print on a capsule and/or lid includes graphic motifs that accurately define the type of coffee contained in the capsule. Various colour and design combinations make it easier to target specific consumers.

Aluminium capsules are a recyclable, impermeable, oxygen-barrier packaging that protects the product from a loss of aroma and external influences such as light and contamination, and extends the product's shelf-life. Aluminium ensures a 100% barrier that, on the one hand, protects the content and, on the other, has graphical potential to make the product recognisable on the market. Since aroma is one of the key determinants of coffee products, aluminium is highly suitable for packaging this product.

It should be noted here that the final packaging is not intended only for coffee. The capsules can be filled with any other type of powdered foods, provided that the final beverage can be prepared in coffee makers that are available on the market.

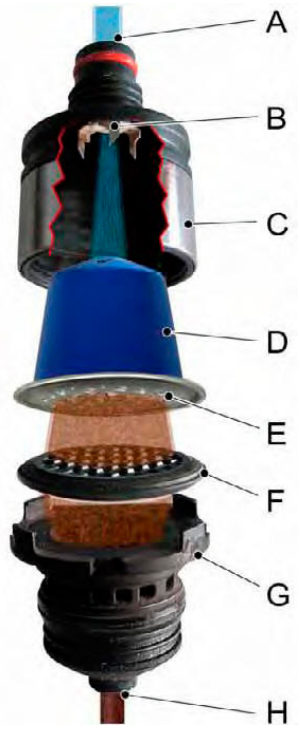
Considering the fact that the world coffee production in 2018/2019 is estimated to be 3.7% higher than in the previous year [1], the market potential is quite extensive. Current trends in coffee consumption include the individualisation of consumption, which makes the product even more exclusive and special.

Figure 1: Rotocoat 1350/350

Aluflexpack Novi d.o.o. ("Aluflexpack" or "AFP") has been developing adequate materials for Aluminium single serve portion capsules for drinks for years on the existing machines and intensified and finalised both the developments and industrialisation of after the installation and commissioning of the new machine. Sophisticated technological processes have been defined and numerous tests were performed to make sure that the machine and the whole setup could assure reliable production of refined aluminium foil at highest quality. AFP's R&D and technology team has been constantly working on enhancing the technological process. Intensive and resource intensive re-definition and thorough re-testing of the whole technological process and product is required after any change of any technical or technological parameter.

Laboratory tests are included at all stages of the process in order to monitor all relevant quality parameters. Migration tests are carried out to confirm the safety and wholesomeness of the material. Controls are carried out with appropriate food simulants and under conditions representing the so-called "worst case scenario". In this context, for example for the material to be used for coffee capsules, the capsules are intended for long-term contact with ground coffee at room temperature and with hot water during the brewing process (up to 2 minutes at a maximum water temperature of 90°C). The final product must comply with applicable European [2], German [3] and Swiss [4] regulations currently in force as well as with the rules and regulations of the US Food and Drug Administration [5], including any applicable amendments thereto.

Illustration of the elements and operation of one type of coffee making machine



The capsule holder (C) encloses the coffee capsule from above (D) and presses it against a pyramidal plate with its edge (F).

The capsule holder and the coffee capsule form a hermetically-sealed brewing chamber. The three spikes (B) in the upper part of the capsule holder penetrate the aluminium foil of the coffee capsule. Hot water is pressurised into the brewing chamber (A). The hot water pressure rises inside the coffee capsule, enabling the penetration of the membrane (E) from the underside.

The coffee is brewed in the capsule and conveyed through the pyramidal plate (F) in the holder (G) to the coffee outlet (H).

Figure 2: Operation of an adequate coffee maker [6]

Illustration of one possible manufacturing process for aluminium lids

Figure 3: Production process flow chart for the aluminium lid

The technological process for the lid is defined for two options: unprinted and printed.

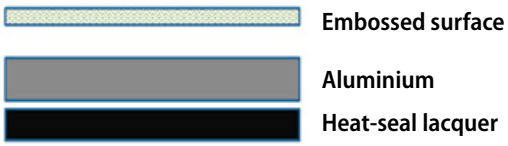


Figure 4: Technological process, unprinted lid foil

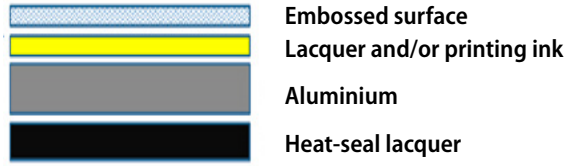


Figure 5: Technological process, printed lid foil

Illustration of one possible manufacturing process for aluminium cup foil

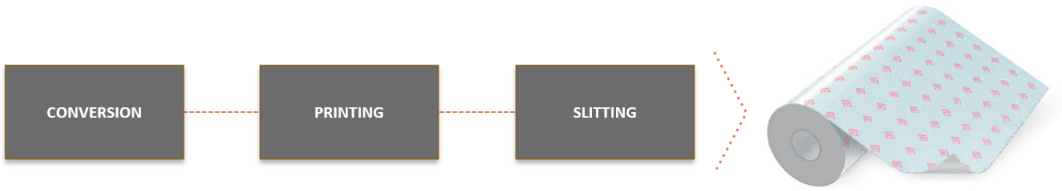


Figure 6: Production process flow chart for the production of aluminium cup foil

There are several technological processes and specifications used for single serve portioned ingredients, for example:

Figure 7: Technological process, unprinted lacquered cup foil

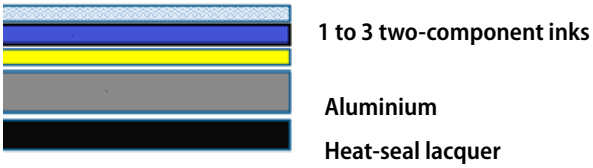


Figure 8: Technological process, printed lacquered cup foil

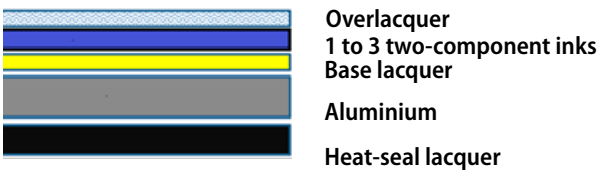


Figure 9: Technological process, printed lacquered cup foil (alternative)

2 MATERIALS AND METHODS

2.1 Equipment

At AFP, several machines and technologies can be and are used for manufacturing the capsule container and lidding foils for aluminium based single serve portion capsules for drinks. The copper-plated printing technique is used, while lacquering can be performed with the use of flexo or semi-flexo technology. The viscosity of the inks used is measured and controlled at each printing unit. The dryers on the machine have a high capacity for drying inks, lacquers and solvents, while vapours are collected and either recuperated or burned, e.g. in the Regenerative Thermal Oxidizer (RTO). The machine is equipped with devices for a 100% quality control of lacquered and printed foils that also detect foil porosity with the help of equipment for measuring the thickness of the lacquer application, print register control equipment, and a spectrophotometer.

2.2 Materials

During the product development, aluminium foils for lids and cups of various thicknesses and alloys were tested. The currently used lid alloy has the required strength, while the cup alloy has the necessary mechanical properties allowing required deep drawing capability. Heat-seal lacquers for the aluminium foil of the cup and lids have a high sealing strength to prevent the containers from cracking when brewing coffee. The printing inks and protective lacquers have a high affinity in order to resist mechanical stress and high temperatures.

2.3 Testing Methods

The quality tests for both the input material and finished product are performed simultaneously during the production process. Some of the tests include: the mechanical properties of pure aluminium (grammage, thickness, breaking strength), the die height in embossed lid foils, the sealing strength of heat-seal lacquers, a lacquer corrosion test, the thermo-stability of the lacquer, a MEK test (wear resistance), and a water test to simulate the conditions in the coffee maker. Equipment for manual ink application, a colorimeter, a gas chromatograph, a vacuum chamber, and an electronic micrometer were also used during the development.

3 EXPERIMENTAL PART

A particularly challenging aspect of the process was the durability and robustness of the lid foil, as it undergoes extreme mechanical, pressure and thermal loads during the beverage preparation process. Some of the examples are illustrated in Figures 10.

Every application has it's own specific requirements – the machine functionality ("serving process") and the product type and properties ("final product") define the key requirements and define both the development targets and quality process criteria. For example, for single service coffee application, coffee brewing was simulated in an original coffee machine and the results of even slightest change in the specifications or process can have significant impact on the quality of the result as can be seen in Fig 10: the pictures of the golden foil (a and b) show an intact mesh, without the ink/toned lacquer falling off, while the mesh of the silver foil (c) is in poor condition.

a)  b)  c) 

Figure 10: Impact of perforation, temperature and pressure on the lid

The sampling of lids for the vacuum tests involves manual manufacturing of closed cups: the cups are filled with water and the lids are sealed using a circular welding machine under the prescribed sealing conditions: temperature, time and pressure. The Dinkelberg Analytics cylinder is half filled with water [7] before the sealed capsules are added. The pressure in the cylinder gradually increases, with the actual pressure being displayed on the machine screen. Once the first bubbles appear, the actual pressure sustained by the capsules is recorded.

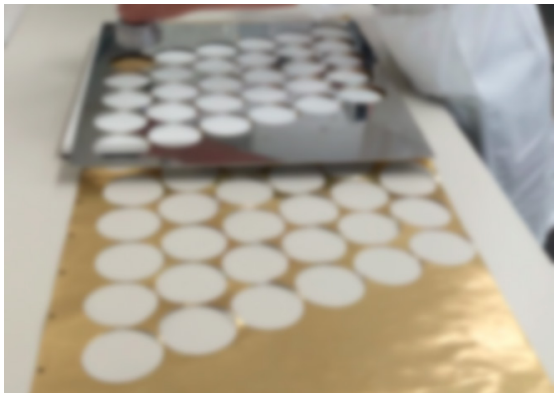
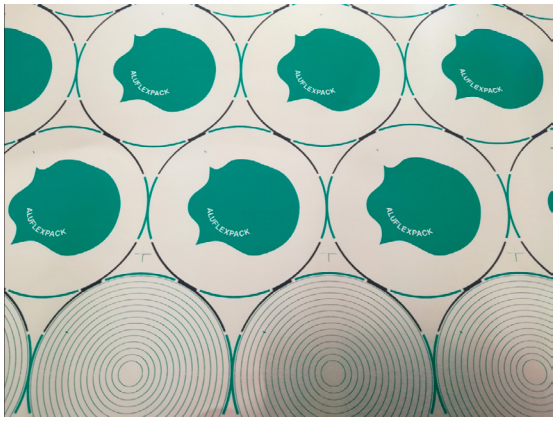


Figure 11: Sampling for the pressure testing of the lid's aluminium foil – vacuum test

The mechanical properties are measured by the ZwickRoell machine. The samples were prepared with a double-bladed cutter and tested (tensile strength/breaking force, elongation). The values of the breaking force and elongation are shown on the machine screen.

Figure 12: ZwickRoell machine for measuring the tensile strength of aluminium



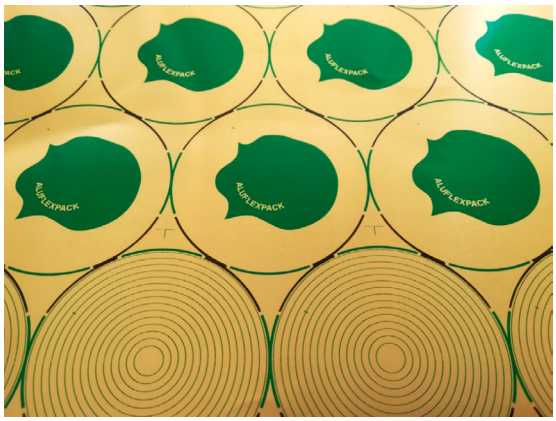


Figure 13: Lacquered cup aluminium foil

During the development of the aluminium foil for cups, special attention was paid to the interaction of individual layers (the aluminium, lacquers, primer, ink and protective layers) to avoid a distortion of the printed graphic motifs. The printed samples underwent deep drawing, and based on the feedback the progression of the anilox rolls was corrected and the grammage of the coating defined for each individual layer.

4 RESULTS

4.1 Results for the lid foil

The tests were performed on a variety of aluminium alloys of various thicknesses. Figure 14 illustrates an example of the testing of three different alloys of the same thickness. Alloy No. 2 boasts sufficiently high tensile strength and elongation, i.e. a high plasticity important for further aluminium forming.

4.2 Results for the cup foil

The cup foil test results show the best properties for the following composition: protective lacquer – ink – priming lacquer – aluminium – heat-seal lacquer. The defined grammage of the heat-seal lacquer coating, lacquer shade, ink, top coat lacquer and oil guarantee the end consumer that the cup meets all quality and safety requirements.

5 DISCUSSION

Experimental research conducted under the project "RAPID - New product development and improvement of technological processes through the implementation of experimental research of Aluflexpack Novi Ltd." incorporated various experiments for ink and lacquer coating, such as semi-automatic flexographic printing presses, various anilox rolls, as well as coating in one or more production steps and led to notable process optimisation and recent patent application documenting the know-how generated.

Typical structural / production related material defects that occurred during production and testing were described as "orange peel", indents and scratches.

When simulating the coffee brewing process, capsule defects were identified every now and then, such as the cracking of the golden lacquer at the capsule edges as a result of poor adhesion and required fine tuning of the processes and specifications.

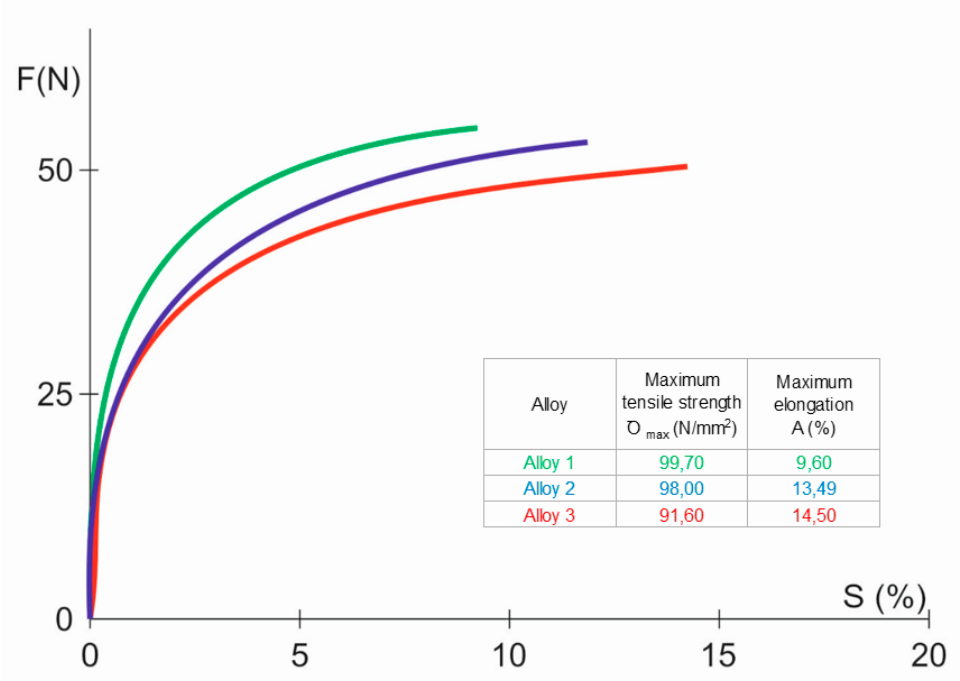


Figure 14: Comparison of the mechanical values of three different alloys of the same thickness

Development and testing of the lacquering application was carried out also by varying the viscosity of the lacquer aiming at finding best possible lacquering parameters for existing equipment and application and in order to achieve the correct quality characteristics for the product together with an even and accurate process application. The results showed that on our equipment a higher-viscosity lacquer had a better overall performance.

6 CONCLUSION

Installation of Regenerative Thermal Oxidizer (RTO) enables energy recovery and waste heat is used for heating /cooling of production premises. Integrated production process on the new machine led to reduction of product scrap of up to 5 %, increase of production capacity due to increased processing speed, reduction of aluminium consumption per unit of new product of up to 8% and also significant reduction of the transportation cost and storage of semi-finished products. The new production setup led to reduction of consumption of natural gas for heating of technological oil by up to 60% per ton of product.

Research carried out by S. Edvardsson, P. Henriksson, F. Regnell and H. Winther [9] on the lifecycle of coffee packaging (either filters or capsules) shows that both coffee-making methods have a similar environmental impact. The difference lie in the use of different packaging materials and the coffee bean quantity used. For comparison, filter coffee (for one cup/portion) uses up significantly more resources than a single coffee capsule. According to data from the official pages of "Gesamtverband der Aluminiumindustrie e.V." [10], when it comes to the waste and energy balance, one of aluminium's great advantages is that it can be almost endlessly recycled without losing its quality. Recycling boosts its mechanical properties and deep-drawing quality. Non-magnetic aluminium is separated from other materials and burnt in so-called pyrolytic ovens. Pyrolysis is a process that takes place in an inert atmosphere (decomposition in the absence of oxygen) in multi-chamber furnaces where in the first phase substances such as ink, label stickers or other residues inside or on the packaging are separated from the aluminium. Energy is released in the form of heat (reaching a temperature of 450-500 °C, with a holding time of 30-60 minutes). In the second phase, the purified aluminium gets melted and cast in ingots or blocks, representing the start of reprocessing aluminium into a finished product. Several European countries have well-developed systems for the collection of used coffee capsules, separating the capsule content and shredding the aluminium packaging so that it can undergo pyrolysis.

Aluminium capsule is an attractive possibility for single-use applications, a wide range of individualized products made it possible to satisfy the preferences and expectations of consumers and their lifestyles. Aluminium capsules fully preserve the coffee aroma. Roast ground coffee is hermetically sealed, fully developing its aroma only upon brewing. In addition these aluminium capsules can be used as the final packaging for any type of powdered foods, such as tea or vitamin and similar hot drinks. Aluminium represents a 100% barrier, is impermeable, extends the shelf life of the final product, is recyclable and an alternative to plastic. Single serve brewing systems are easy to use, fast and clean. The energy used is reduced to the quantity needed for the preparation of one cup of coffee, since there is no residue to discard or waste additional energy on. Aluminium capsules save valuable resources and can be efficiently recycled by using an adequate disposal system, thus closing the cycle.

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7 REFERENCES

[1] International Coffee Organization, "Coffee Market report – September 2019, available at: http://www.ico.org

[2] REGULATION (EC) No 1935/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on materials and articles intended to come into contact with food, including any applicable amendments thereto; COMMISSION REGULATION (EU) No 10/2011 on plastic materials and articles intended to come into contact with food, including any applicable amendments thereto

[3] German "Lebensmittel-, Bedarfsgegenstände- und Futtermittelgesetzbuch (LFGB)", including any applicable amendments thereto, together with "Bedarfsgegenständeverordnung (BedGgstV)", including any applicable amendments thereto, in view of the overall migration and specific migration of monomers and additives under the specified conditions of use

[4] Swiss regulation on food contact materials and articles (SR 817.023.21), including any applicable amendments thereto

[5] FDA 21 CfR, title 21, §§ 175.300, including any applicable amendments thereto

[6] Kapselmaschinen Aufbau und Funktionsweise von Kaps, https://forum.iwenzo.de/kapselmaschinen-aufbau-und-funktionsweise-von-kaps--t53054.html

[7] https://dinkelberg.de/verpackungstester/

[8] Edvardsson S., Henriksson P., Regnell F., Winther H. (2016), "Comparative LCA of coffee: capsules vs brick pack", KTH Stockholm 16-12-2016

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