LEISTER

How can Cardboard-Based Packaging be Sustainably Sealed?

EXPERTISE | Hot Air for the Food and Packaging Industry



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Management Summary

Starting Point

The use of cardboard and paper-based packaging in the food and beverage industry has been increasing for years. Due to the increased environmental awareness among consumers and pressure on manufacturers, it can be assumed that this type of food and beverage packaging will become even more prominent in the future. Food packaging made of cardboard or paper-based materials can be used in various ways, for example: as packaging for liquid foods such as dairy products or drinks such as juices or iced tea, or as paper cups for coffee and cold drinks. Solid foods, such as popcorn, are also sold in this kind of packaging. According to global market observations, the market for liquid packaging is expected to grow to over USD 22 billion and the market for paper cups to around USD 17 billion by 2028.

Aims

Producers of filling lines, packaging material production lines and paper cup machines use various technologies to seal the beverage packaging, the prefabricated packaging material or to manufacture the packaging. Depending on the raw material, type of processing machine and system design, each of these processes has advantages and disadvantages. Filling and welding machine operators require a sealing process which offers process reliability, achieves consistent high weld seam quality and corresponds to machine capacity. At the same time, purchasing and operating costs of the systems should be low.

Analysis and Practical Test

Various welding and sealing processes for cardboard and paper-based food packaging were examined for this expertise. The most common methods for welding or sealing these materials have been compared. It was found that the end product's quality requirements, especially with high machine capacity, play a key role in the selection of the appropriate sealing process. Aside from investment and operating costs, the operational reliability of the system is another vital aspect. Hot air is often used for the sealing process. The research analyzed the technical limits of this process and types of material which can be sealed with hot air. It was also tested whether high-capacity machines can be operated efficiently with hot air and whether this has an impact on the quality of the sealing.

Recommendations

Sealing coated cardboard or paper-based packaging materials with hot air works very well even with high machine capacity and low cardboard coating thickness. The weld seam produced is of high quality, which facilitates reliable operation. In the meantime, technologies have become available to operate air heaters efficiently and with minimum resources. Here, hot air recirculation plays an important role in keeping operating costs down and using the machines sustainably.

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1. Introduction

The use of cardboard and paper-based packaging in the food and beverage industry has been increasing for years. Although food has been consumed in paper and cardboard packaging for decades, the growing awareness of sustainability and environmental protection all around the world is increasing the importance of this packaging.

Cardboard and paper-based packaging is versatile and easy to print on. It is used for liquid and solid foods as well as drinks. It is widely used in the food industry. Just a few examples:

- Milk and juice cartons
- Packaging for frozen products such as fish and pizza
- Packaging for dry products such as pasta, rice, biscuits and salt

In this white paper, the authors will focus on one specific part of the manufacturing process for liquid food packaging, namely the welding or sealing process.

Out of the many product groups of cardboard packaging, two important product groups are analyzed in more detail:

- Packaging for dairy products and fruit juices (liquid packaging)
- Paper cups for coffee, tea or other drinks, for foods such as ice cream, fruit, vegetables and salads (bowls) and for instant food, for example noodle soups. Dry products such as popcorn are also sold in cardboard cups.

What the groups of cardboard and paper-based packaging have in common is that their respective base material has a plastic coating, which can be welded or sealed.

The question of how the welding or sealing process step in the production of this packaging can be optimized in a reliable, economical and resource-saving way by using hot air is in focus. In order to get to the root of this question, various practical approaches will be analyzed and compared in detail. This enables a comprehensive analysis of current processes. On this basis, innovative solutions and potential improvements are identified in the hot-air welding and sealing of cardboard and paper-based food and beverage packaging.

2. Properties and Functions of Cardboard or Paper-Based Food Packaging

Cardboard or paper-based food packaging has become an integral part of our modern everyday lives. It protects food and drink from external influences such as air, moisture and light, and at the same time it acts as a barrier against contamination and germs. It also protects food from oxidation and moisture loss, keeping it fresh for longer. Spoilage is slowed down, which means a longer shelf life. In addition, labels on the packaging provide important information about ingredients, nutritional values, origin, weight, as well as storage and processing instructions.

Packaging also makes it easier to transport and handle food. Different portion sizes help reduce food waste. Visually attractive packaging also attracts the attention of consumers, which increases sales and plays a vital role in brand communication.



3. Structure of Cardboard or Paper-Based Food Packaging

Depending on the type of packaging, contents as well as logistics and retail requirements, cardboard packaging has different structures and layers made of different materials. The following table gives an overview of the number and different types of layers of cardboard or paper-based packaging.

EXTERIOR	**EXTERIOR**	**EXTERIOR**	**EXTERIOR**
Polyethylene (PE)	Polypropylene (PP)	Polyethylene (PE)	Polypropylene (PP)
Cardboard	Cardboard	Cardboard	Cardboard
Polyethylene (PE)	Polypropylene (PP)	Polyethylene (PE)	Polypropylene (PP)
PRODUCT	Bonding agent	Bonding agent	Bonding agent
	Aluminum foil	Ethylene vinyl alcohol (EVOH)	Aluminum foil
	Bonding agent	Bonding agent	Bonding agent
	Polypropylene (PP)	Polyethylene (PE)	Ethylene vinyl alcohol (EVOH)
	PRODUCT	**PRODUCT**	Polypropylene (PP)
			PRODUCT

Variants of the composite structure of packaging materials of different cardboard types

Unprocessed cardboard is produced on cardboard machines that have several sheet-forming devices, depending on the number of fiber-based cardboard layers. Combinations of various Fourdrinier and former concepts are usually used, with headbox systems designed in one or more layers.

In contrast to conventional folded box cardboard, unprocessed cardboard for food packaging requires special mass sizing to prevent the penetration of liquid packaging components into the cardboard via exposed cut edges. Dual systems of alkyl ketene dimer (AKD) and resin glue or monosystems based on AKD are mostly used as adhesives.

For beverage packaging with a package volume of 1,000 ml, the average weight-related PE content of the packaging material is around 20–25 %. The unprocessed cardboard accounts for 70–80 %. The proportion of aluminum foil is around 0–5 %.

4. Liquid Packaging

When developing carton packaging (including beverage cartons) for liquid foods (such as dairy products) and beverages (such as fruit juices), the aim was always to reduce the packaging weight and simplify transportation and storage. At the same time, they wanted to improve the shelf life of liquid foods and drinks. At the end of the 19th and beginning of the 20th century, patents were already registered for this in the USA. These were designed to replace glass bottles with leak-proof cardboard containers. Pioneers such as John Van Wormer (1856–1942) were granted patents for leak-proof cardboard containers such as the "Pure-Pak®" product. Development gathered pace in the 1930s and 1950s, when companies like Elopak and Tetra Pak were founded and innovative technologies such as extrusion coating with polyethylene (PE) were introduced. The Swedish companies Åkerlund & Rausing and Tetra Pak played a significant role in this. The Swiss SIG Combibloc group, the world's second-largest system provider of liquid food packaging, has important roots that go back to Jagenberg AG and its "Perga packaging." Advances in research and development have led to high-tech and resource-saving solutions, including cardboard-based packaging for fresh products and food with an extended shelf life.

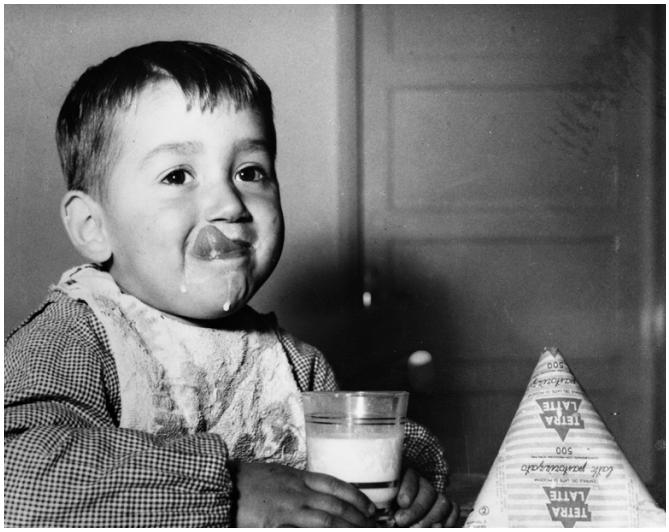


Fig. 1: Tetra Pak 1950



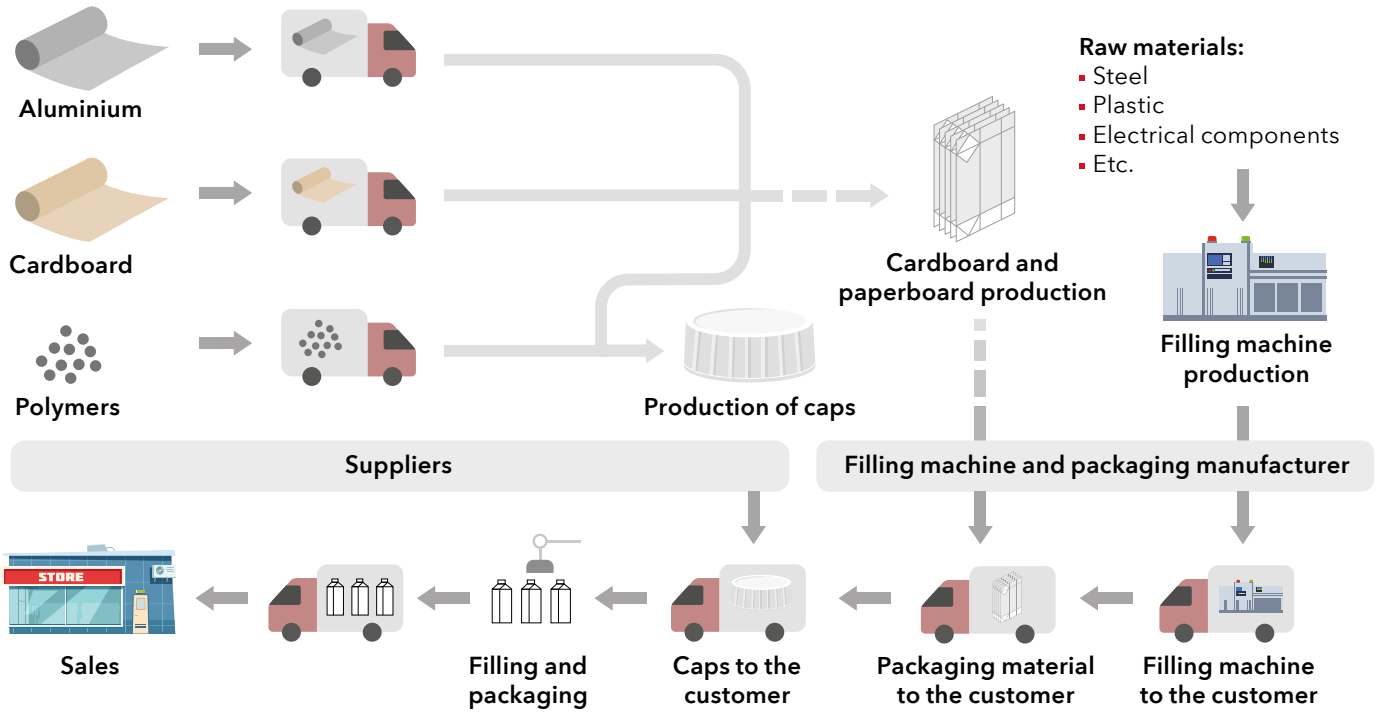
Fig. 2: Tetra Classic shop window, Tetra Pak 1957

Largest manufacturers of beverage cartons and filling machines

Company	Based in	Market share
Tetra Pak	Switzerland	75 %
SIG Combibloc	Switzerland	10 %
Elopak	Norway	2 %
Greatview Aseptic Packaging	China	2 %
Adam Pack	Greece	No data
Anhui Cole Pak	China	No data
Asepto	India	No data
DNP	Japan	No data
Hangkuk Packaging	Korea	No data
IPI	Italy	No data
Nampak	South Africa	No data
Nimco	USA	No data
Nippon Paper	Japan	No data
Obeikan Liquid Packaging	KSA	No data
Pactiv Evergreen	USA	No data
Shikoku Kakoki	Japan	No data

Global market shares of companies (based on 250 ml packaging)

Product life cycle of beverage packaging



Market Development

The global beverage carton market was valued at USD 16.8 billion in 2021 and is expected to grow to USD 22.44 billion by 2028. This is with a compound annual growth rate (CAGR) of 4.2 % in the forecast period 2021–2028 (see Fortune Business Insights).

Demand for beverage cartons, especially for milk and dairy beverages, is increasing in emerging countries in the Asia-Pacific region and Latin America, for example, due to their large, young populations. These young people prefer convenience products that suit their on-the-go lifestyles. Easy-to-transport and tamper-proof packaging allows them to travel and work for long periods of time without worrying about spillage or spoilage. Drinks in this kind of packaging are also available in every supermarket.

This trend is expected to contribute to the growth of the global beverage cartons market during the forecast period.

To meet rising demand, producers of dairy products and other beverages are increasingly focusing on improved product storage and the use of sustainable packaging options, such as durable cartons with a lower plastic content. Consumers are increasingly aware of the environmental impact of traditional plastic packaging, which is encouraging the industry to use more environmentally-friendly alternatives.

Production of Beverage Cartons (Packaging Material)

The technical requirements for beverage cartons (usually called packaging material before they are filled) are mainly determined by the following criteria:

- Compliance with all legal requirements and food safety regulations
- Protection of sensitive ingredients in the filling product, e.g. vitamins, from environmental factors (impermeability to air and light)
- Avoiding interactions between the packaging material and filling (taste and odor neutrality)
- Guarantee of all packaging functions during transport, handling and storage (leak protection, mechanical stability, durability of the printed image)
- Ensuring the required processing properties (printability, scoring characteristics*, dust-free, sealability and abrasion resistance)

* Scoring characteristics are the ability of a paper or cardboard material to get creases or notches through a technical process. This process is carried out by machine and enables boxes to be folded more easily and accurately at predetermined points. The grooves worked into the paper or cardboard are usually used to produce a folded edge later.

The individual requirements for the packaging material depend on the product and its properties. The durability criteria of the product under different environmental conditions play a key role here. The specific requirements of the filling company (e.g. dairy or beverage producer) in terms of packaging formats and external appearance are also important criteria. The requirements are implemented primarily through the targeted selection of materials used for the packaging and their processing technology.

Fresh products, for example fresh milk or preservative-free natural juices, have a short shelf life and must be stored and transported within the cold chain. To ensure this, the packaging must have an effective barrier against moisture and microorganisms. To this end, the unprocessed cardboard of the packaging is provided with a PE extrusion coating on both sides.

Products with a longer shelf life that are stored at room temperature are filled aseptically or hot and the packaging material requires an additional barrier made of PE, PP, EVOH or aluminum to protect against environmental factors such as air, moisture and light. Aseptic packaging processes are distinguished by the fact that the filling product and packaging material are sterilized separately and filling takes place in a closed, sterile system. The sealing immediately afterwards prevents microorganisms from penetrating the filling material.

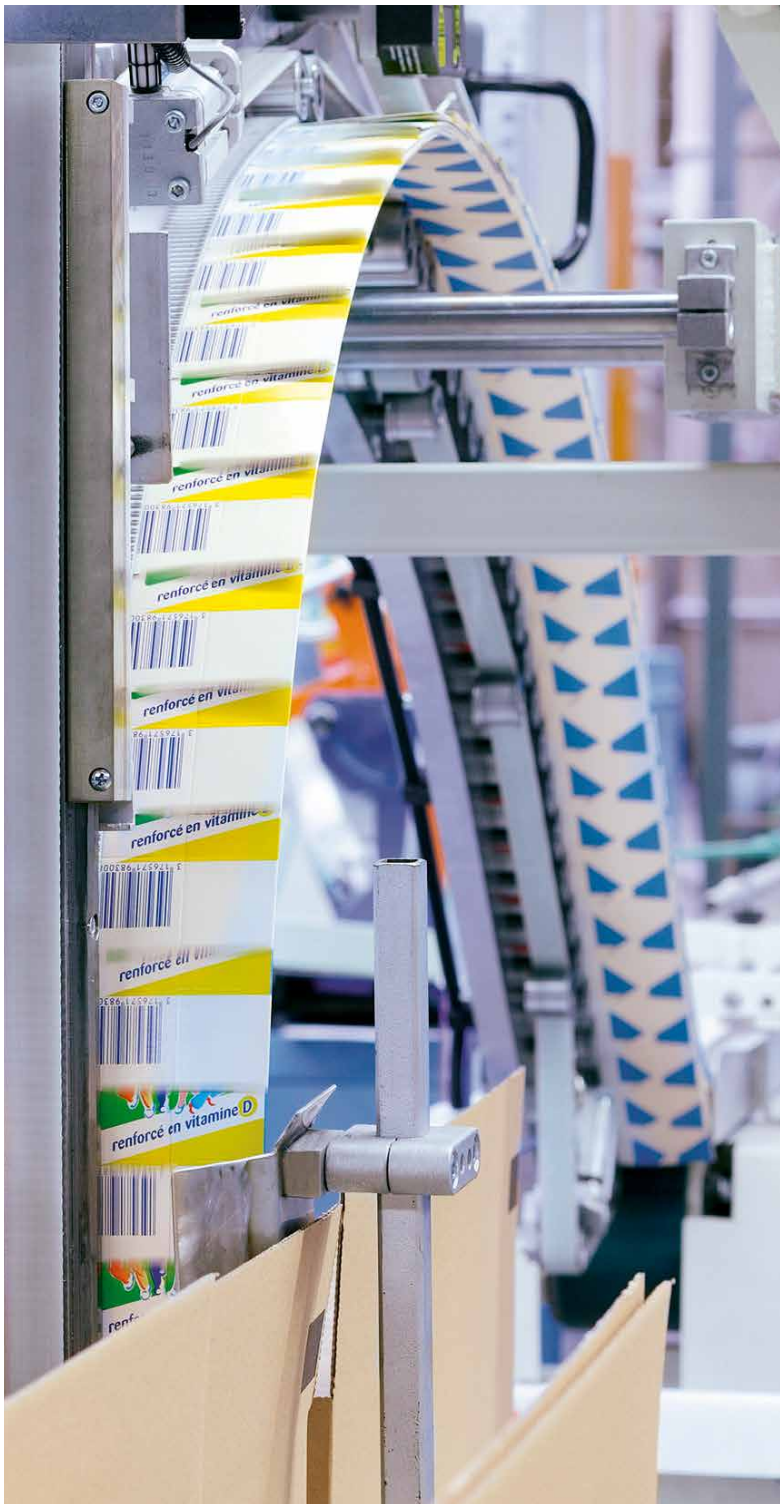
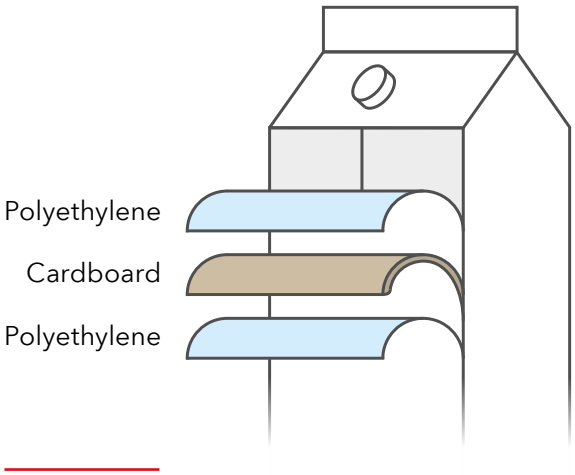
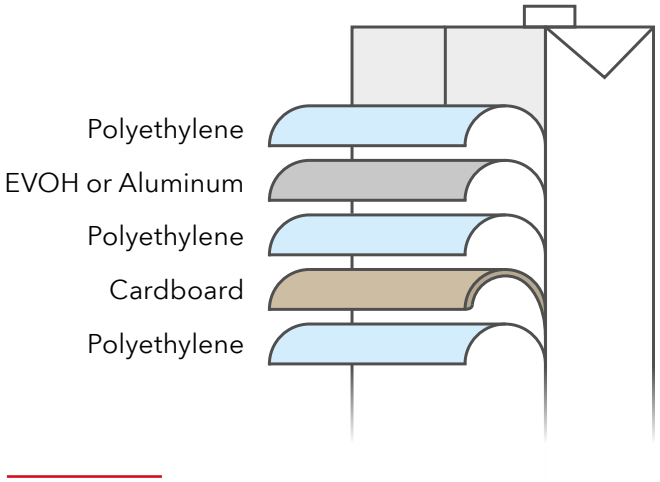


Fig. 3: Production of the paperboards (packaging material), SIG Combibloc n.d.



Beverage carton for fresh products
(storage continuously within the cold chain,
short shelf life)



Beverage carton for long-life products
(aseptically or hot-filled, storage outside the cold chain
at room temperature, long shelf life)

Preliminary stages of packaging production

The production of packaging materials is to be regarded as a technological sub-process of the complex filling technologies for liquid foods. Two different basic technologies have been established: the roll-fed method and the sleeve method. They differ in the initial format of the packaging materials that are fed into the filling machine at the end customer (filling company).

Roll-fed method

The printed and coated cardboard is fed into the filling machine as a roll. The folding, sealing and filling take place at the same position within the machine. This process is mainly used by the world market leader Tetra Pak.

Packaging production process in the roll-fed method:

1. Unprocessed cardboard (roll material)
2. Printing (e.g. flexo printing or offset printing)
3. Grooving/punching
4. Internal coating
5. Additional layers for aseptic packaging material e.g. aluminum
6. External coating
7. Cutting rolls to application-specific width
8. Send packaging material (roll material) to the filling company

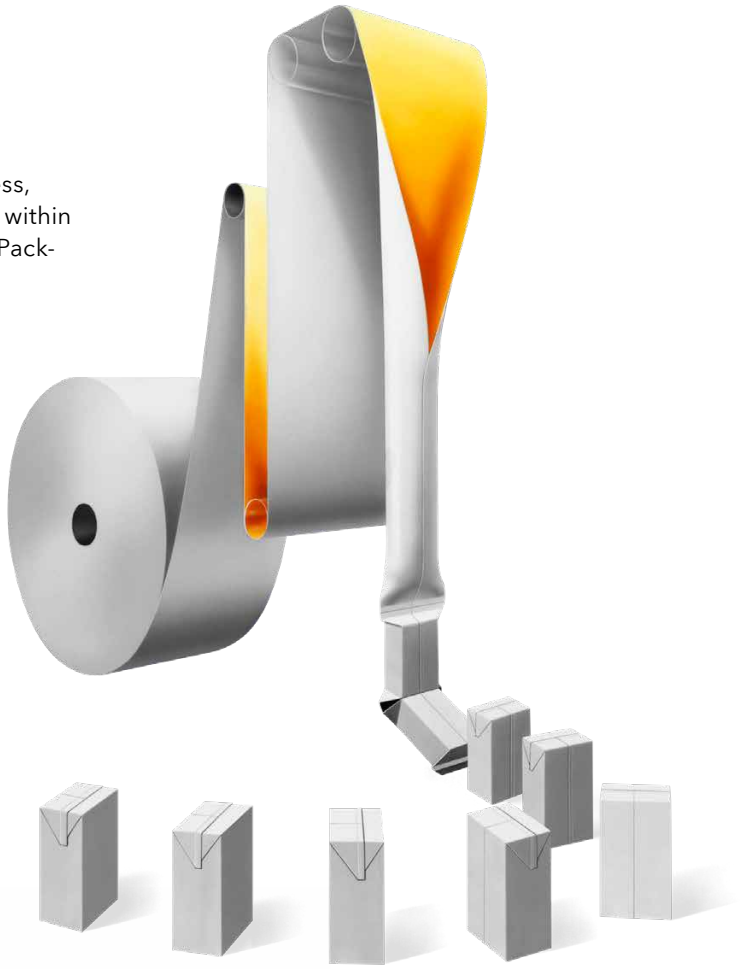


Fig. 4: Schematic representation of the roll-fed process, packaging (folding and sealing) and filling take place within the machine. Professional Association of Cardboard Packaging for Liquid Foods. V (FKN) n.d.



Fig. 5: Filling machine for roll-fed method with loading station for packaging material roll, Tetra Pak 2020

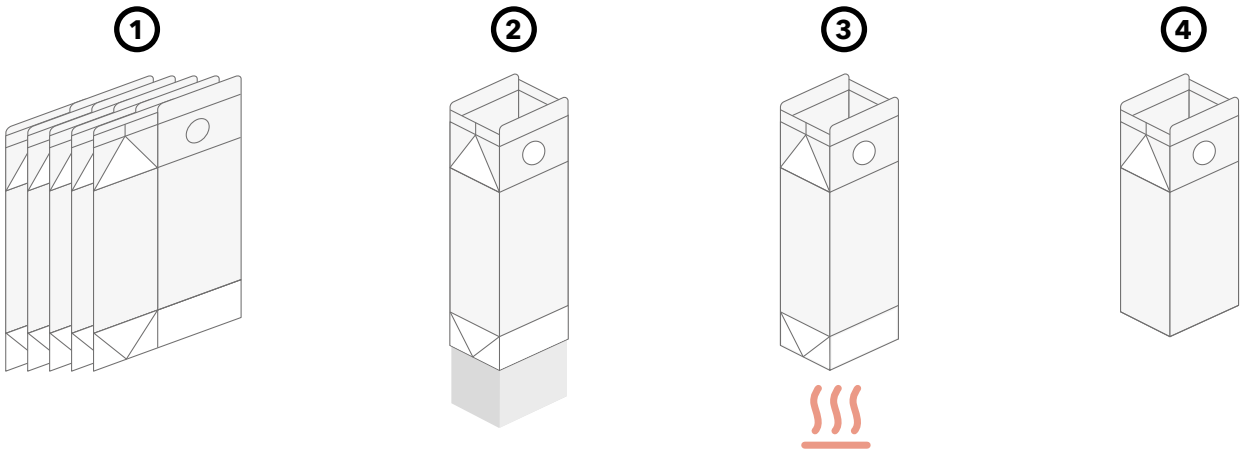
Sleeve method

In the sleeve method, also known as sleeve filling, the filling machine is loaded with the pre-produced carton sleeves (also commonly known as "blanks" in the industry). After sealing the base, the packaging is sterilized and then filled and sealed.

Packaging production process in the sleeve method:

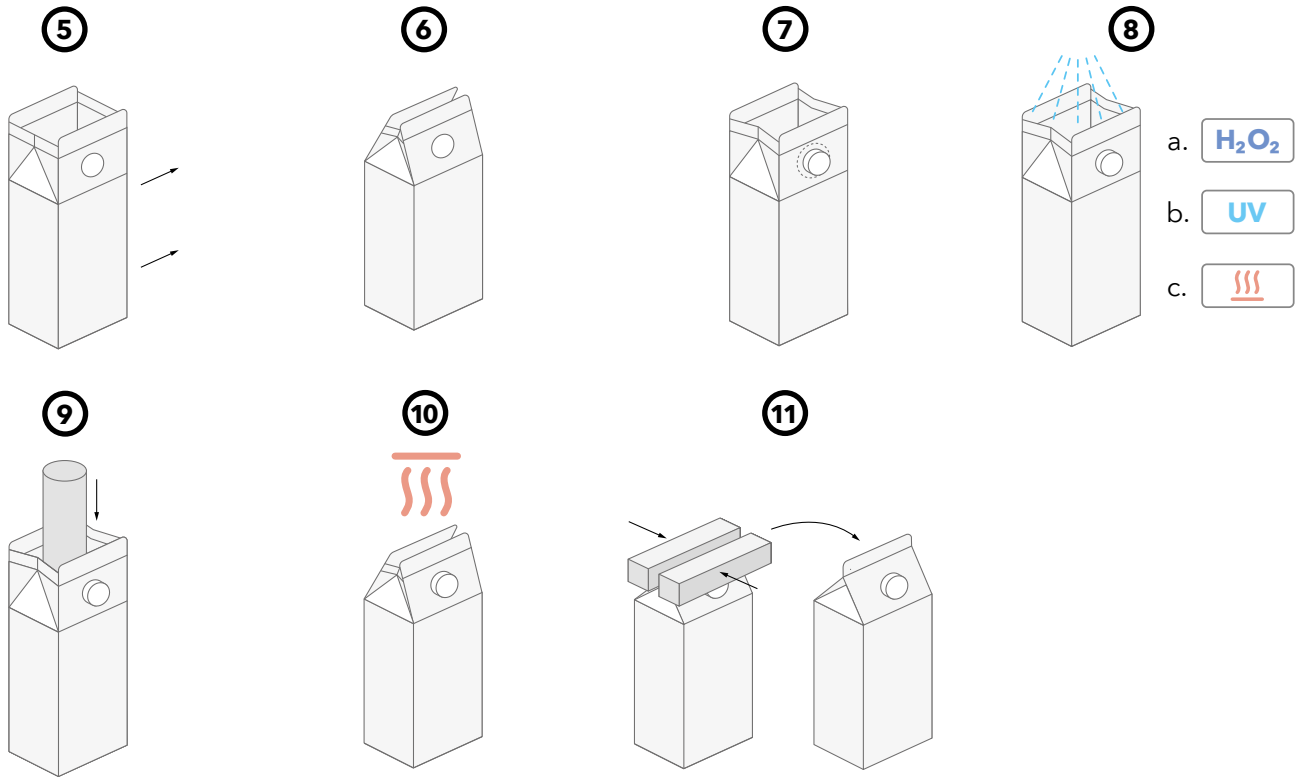
1. Unprocessed cardboard (roll material)
2. Printing (e.g. flexo printing or offset printing)
3. External coating
4. Cut format
5. Internal coating
6. Additional layers for aseptic packaging material e.g. aluminum
7. Grooving, if necessary, punching
8. Folding and longitudinal seam welding
9. Send packaging material (sleeve) to the filler

Filling and capping process for sleeve method



Detailed description of the filling and capping process using the sleeve method:

1. To begin with, the machine is loaded with the packaging material (also known as blanks or sleeves).
2. The packaging material is unfolded and pushed horizontally over a mandrel to initiate the rest of the process.
3. The lower part of the packaging is heated by a temperature-controlled hot air system.
4. The cardboard flaps are folded inwards and pressed against the mandrel, creating a tight weld or seal.



5. After sealing, the packaging is removed from the mandrel and transported to the next station by a conveyor chain.

6. Here, the upper part of the carton, also known as the gable, is pre-folded to guarantee secure folding and sealing after filling.

7. The spout with the cap is attached using ultrasound.

8. This is followed by disinfection in three stages:
   a. First, hot hydrogen peroxide is sprayed into the packaging.
   b. Then the hydrogen peroxide is activated with UV light.
   c. Finally, the excess hydrogen peroxide is evaporated with hot air.

9. The packaging is now filled with the desired product, such as milk or fruit juice.

10. The carton is pre-folded again, with upper part heated using hot air to prepare it for sealing.

11. The packaging reaches the sealing station, where jaws press the carton together to ensure a tight seal.

    This type of packaging is known as a "gable top" as it looks like a roof gable.

    After the sealing process, the beverage carton leaves the machine and is transported to the packaging machine on the conveyor belt.



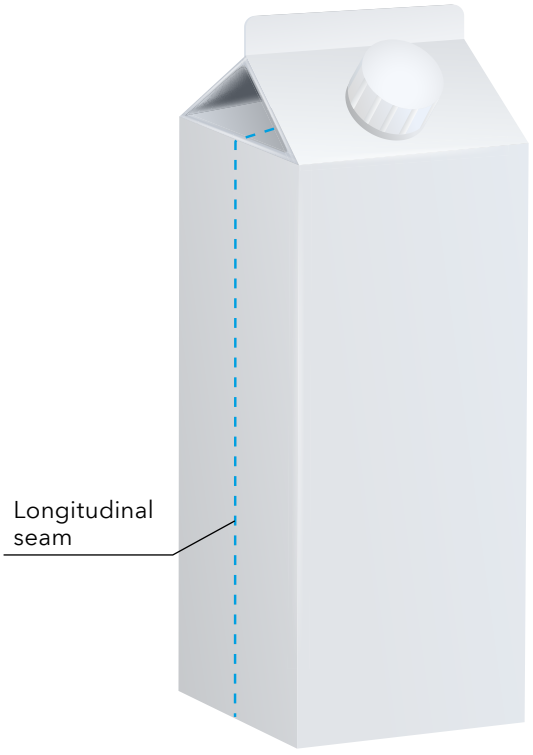
Fig. 6: Filling machine, SIG Combibloc n.d.



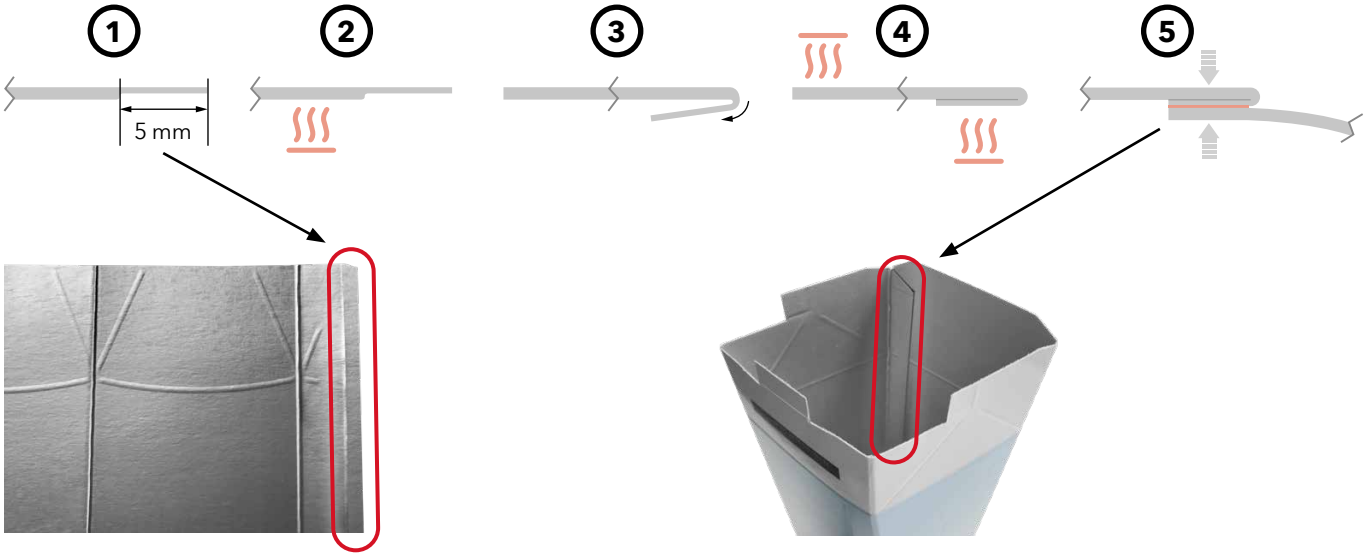
Fig. 7: Filling the prefabricated sleeves or blanks, SIG Combibloc n.d.

Welding the longitudinal seam

Producing the packaging material in the sleeve method is a complex process that involves many steps. The decisive factor here is longitudinal seam welding, also known as sealing. Until now, hot air has been used for the sealing process for smaller production line capacities. In high-speed lines, on the other hand, gas-powered welding technologies, known as flame sealing, have been used. This means that a gas flame is used for heat transfer and activation of the cardboard. This special part of the system is known as a flame sealer with an impressive capacity of up to 140,000 sleeves or blanks per hour. This corresponds to a system speed of around 750 m/min.



Process steps for longitudinal seam welding



The longitudinal seam welding process is divided into five steps:

1 Skiving

In this step, the thickness of the cardboard is slit to a width of approximately 5 to 7 mm (depending on the manufacturer) and excess material is removed. The thickness of the cardboard is halved in this area.

2 Heating

The adjacent coated area is now heated intensively over a width of at least 5 to 7 mm. This process prepares the material for the subsequent sealing process by activating the surface and preparing it for the joint.

3 Folding

Now the slit part of the cardboard is turned over, folded and welded to the previously heated area. This process ensures that the newly created edge of the cardboard is coated all around. This is important to prevent the penetration of liquids and to protect the packaging from softening.

4 Heating

As in process step 2, the cardboard is heated to a width of around 5 to 7 mm to ensure precise and permanent sealing.

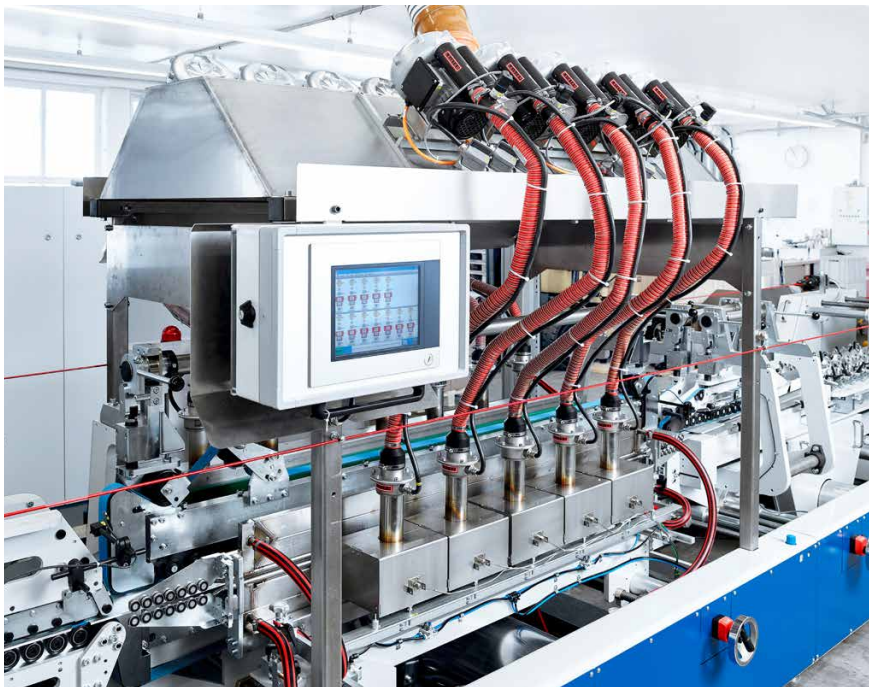
5 Hemming

The final step is the actual longitudinal seam welding. The cardboard is folded into a packaging blank (sleeve) and pressed. This step gives the packaging material its final shape and ensures its stability.

Process steps 1 to 3 make a significant contribution to ensuring that the newly created carton edge is continuously coated. This prevents liquids from penetrating the carton edge, which in turn ensures the quality and durability of the packaging. The careful execution of these steps is crucial for the production of high-quality, functional packaging materials – especially in terms of their watertightness and stability.



1. Section
Process steps 1 to 3



2. Section
Process steps 4 and 5

Line capacity: Up to 140,000 pcs/h
Production speed: approx. 750 m/min
Welding temperature: 750 °C

Challenges when switching to hot air

Despite the efficiency of gas-powered flame sealers in high-speed lines, many packaging manufacturers are showing growing interest in switching to longitudinal seam welding with hot air, even with high-performance machines.

This switch has not proven to be easy in the past. One of the main reasons for this is the extremely short interaction time. To elaborate: The interaction time describes the period during which the carton is guided past the hot air nozzle and exposed to the heat.

To put it more specifically, this means that with a heating section of 1.6 m in length operated with hot air nozzles and a system speed of up to 750 m/min, the interaction time is just 0.13 seconds. Especially developed high-tech air heaters and hot air nozzles are required to transfer the required heat to the carton in this short period of time and to activate the surface for the welding or sealing process. An air temperature of 750 °C is also required to bring sufficient energy into the product.

The heat loss between the air heater and the air outlet at the nozzle must be kept as low as possible. This is achieved by very efficient insulation of the nozzle and ideal routing of the air within the system. The geometry of the nozzle openings ensures precise and efficient heat distribution.

These technologically complex components optimize the interaction between the carton and the heat in a short time. Only by using modern heating technology is it possible to meet the demands in terms of process speed and quality.



1 Air heater

2 Nozzle

Advantages and Disadvantages of the Technologies

Criteria	Gas operation	Hot air
Precision and controllability	⊕⊖ medium	⊕⊕ very good
Uniformity of heat distribution	⊕⊖ medium	⊕⊕ very good
Speed of welding process	⊕⊕ very good	⊕⊕ very good
Energy efficiency	⊕⊖ medium	⊕⊕ very good
Environmental impact, carbon emissions	⊖⊖ high	⊕⊕ none (prerequisite: renewable electricity)
Investment costs	⊕⊖ medium	⊕⊖ medium
Occupational safety	⊖⊖ poor	⊕ good
Maintenance effort	⊖ high	⊕ low
Cost efficiency during operation	⊕⊕ very good	⊕⊖ medium
easy adaptation to new product or different board thickness (presetting)	⊖⊖ time-consuming	⊕⊕ quick and easy, partly automatic
Traceability and quality assurance	⊕⊖ medium	⊕ good
Space requirement in the system	⊕⊕ minimal	⊕⊖ medium
regulatory requirements and certifications	⊖ high	⊕⊖ medium
Oxidation of the welding seam*	⊖⊖ yes	⊕⊕ no

*With the use of gas, there is a risk that the PE surface of the packaging will oxidize in the area of the weld seam. This means that the second weld after the skiving/hemming process may have reduced mechanical strength. This is not the case with hot air.

5. Paper Cups

The history of the disposable paper cup dates back to 1908, when Boston inventor Lawrence Luellen developed a two-part paper cup. He founded the Individual Drinking Cup Company with Hugh Moore, later calling their product the "Health Kup." Originally designed to prevent infectious diseases, the cup also supported the campaign against "tin dippers" (shared drinking vessels made from tin). Its health benefits meant the cup was particularly popular during the time of the Spanish flu. However, the commercial breakthrough came when Moore named the cup after the Dixie Doll Company. The introduction of automatic soda fountains, which filled the cup with two types of ice cream, further strengthened its positive reputation. Dixie cups marked the beginning of the wave of disposable products, including razors, aerosol cans and water bottles.

Paper cups have become indispensable in today's fast-moving world. They are used for drinks such as tea and coffee as well as for many foods such as popcorn, ice cream, soups, pasta, ready meals and others. Their versatility makes them an indispensable part of our everyday lives. From cafés and events to snack stands, paper cups are often the preferred choice alongside plastic cups. With hot drinks, high-quality paper cups with an inner coating keep the heat inside the cup better, protecting the consumer from burns. Easy to handle, they contribute to the practical and hygienic packaging of food and drink. The wide-ranging use of the cups reflects their functionality and adaptability to diverse consumer habits.



Market Development

In 2022, the market for paper cups was estimated at USD 12.58 billion. It is expected to grow to USD 17.36 billion by 2031. This corresponds to an annual growth rate of 3.64 % in the forecast period of 2023–2031. Although the Asia-Pacific region dominated the market in terms of revenue in 2022, North America recorded the highest growth with a compound annual growth rate (CAGR) of 3.68 %.

Key growth factors are the trend towards eating on the go, coupled with rising coffee and tea consumption, which are boosting the use of paper cups worldwide.

Consumers also prefer disposable paper cups for reasons of hygiene, ease of disposal and their hectic lifestyles.

Increasing awareness of environmental issues is driving demand for biodegradable paper cups. Consumers are showing increasing interest in sustainable packaging options, which should further boost market growth. The increased use of environmentally friendly materials in paper cup production reflects a positive trend and contributes to the attractiveness of the market.

Major manufacturers of paper cups

Company	Based in
Benders Papercup	UK, Wrexham
CEE Schisler	France, Thouars
Dart Container Corporation	USA, Mason, Michigan
Detmold Group	Australia, Hindmarsh
Eco-Products Inc.	USA, Boulder, Colorado
Flo Group	Italy, Fontanella
Georgia-Pacific LLC	USA, Atlanta, Georgia
Go-Pak UK Ltd	UK, Bristol
Graphic Packaging International	USA, Atlanta, Georgia
Grupo Phoenix Corporate Services LLC	USA, Miami, Florida
Huhtamaki OYJ Finland	Finland, Espoo
Juno Pack Company	Egypt, Alexandria
Kap Cones Private Limited	India, New Delhi
Konie Cups International Inc.	USA, Miami, Florida
Leetha	India, Ernakulam
Letica	USA, Evansville, Indiana
Lollicup	USA, Chino, California
Pactiv LLC	USA, Lake Forest, Illinois
Solo Cup Company	USA, Mason, Michigan

Not all Cardboard Cups are Equal

People enjoy drinking from paper cups all year round, often without considering the variety of designs and materials available. From single-walled to double-walled cups, thick or thin cardboard, there are many different types of paper cup. The contents also play a role here. We distinguish between cups for hot or cold drinks, ice cream and dry snacks such as popcorn. While consumers rarely think about it, choosing the right cup is an important issue for restaurants, snack bars and retailers. This is not because of the different prices of the cups.

Paper cups are produced in various designs. The most significant are:

- Single wall paper cups
- Double wall paper cups
- Ripple cups
- Environmentally-friendly cups



Single Wall Paper Cups

Single-wall paper cups are available for both hot and cold drinks. A distinction is also made between hot paper cups and cold paper cups. Cups for hot drinks have a thicker cardboard sleeve than cups for cold drinks and usually contain a double inner layer of polyethylene (PE) to prevent leaks. However, heat can penetrate the paper material. This is why it is recommended to use a mug cover to protect against burns when filling the mugs with scalding hot contents. The cups are available in many different sizes and designs. Depending on the quantity purchased, they cost around USD 0.04–0.06 per cup, making them a cost-effective option.



Double Wall Paper Cups

Double wall, insulated cardboard cups have an additional wall to keep coffee and tea warm for longer and protect consumers from burns.
No attachable cup sleeves are required for these cups, which saves costs. Depending on the size and design, these cups cost between USD 0.10 and 0.18 each.



Ripple Cups

Corrugated paper cups are produced with an additional layer of structured insulation. This means they keep drinks warm for longer and no sleeves are required. Ripple cups are named after their textured appearance. They provide insulation and are particularly comfortable to hold. These cups are double-coated with PE, which ensures leak protection and gives them additional elasticity. The price for ripple cups ranges between USD 0.09 and 0.25 each.



Environmentally-Friendly Paper Cups

Not all paper coffee cups are compostable or recyclable because their inner lining is made of a polyolefin-based plastic. For eco-friendly paper cups, a plant-based material called PLA* is used to create the same leak-proof layer. Thanks to these renewable raw materials, eco-friendly coffee cups are compostable and therefore better for the environment than conventional coffee cups.



**PLA is the short form for polylactides, which are colloquially called polylactic acids. To obtain these lactic acids, starch is required, which grows in plants such as maize, potatoes or beets through photosynthesis. When the starch extracted from the plant – in the case of PLA mainly from maize – ferments, lactic acids are produced.*

6. Paper Cup Manufacturing Process

The manufacturing process can be divided into three main groups:

- Manufacture of the unprocessed paper and coating
- Printing and punching out jacket blanks and floors
- Production of paper cups in the cup machine

Manufacturing and Coating of the Raw Cardboard

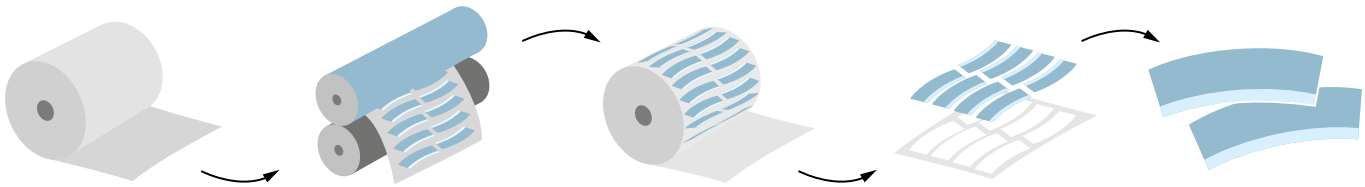
The production and coating of the unprocessed paper is not described in detail in this report because it is not relevant in terms of content and would go beyond its scope.

Printing and Punching out Jacket Blanks and Floors

The production process for the blanks is similar to the production of liquid packaging material and is carried out as follows:

- First, the unprocessed paper, which is usually already coated, is delivered in rolls. Depending on the subsequent use of the paper cup – whether for hot or cold drinks – the paper is given the appropriate coating.
- Depending on the customer's requirements, the paper is then printed on one side (usually flexographic printing). This is rolled up again after printing.
- In the next step, the blanks and bases are punched out of the pre-produced rolls in a separate machine. Precise punching ensures a uniform shape and optimum fit.
- After punching, the cup sleeves and bases are fed into the cup machine.

Production process for blanks



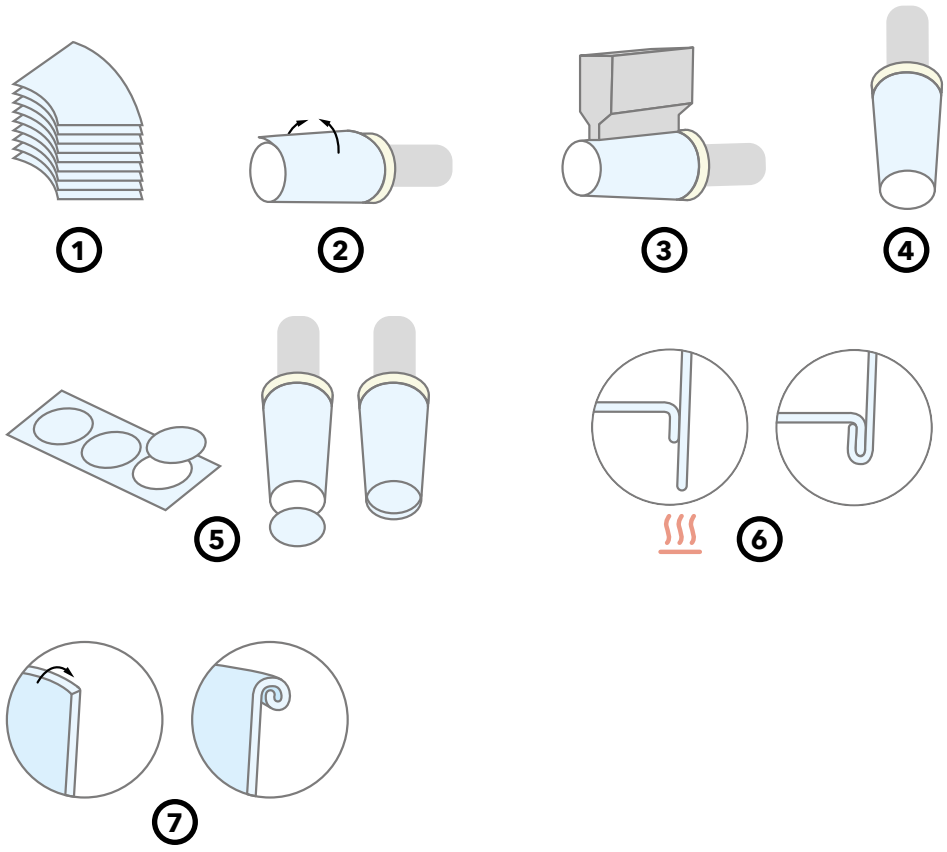
1. Paper roll (coated)
2. Printing machine (e.g. flexo printing)
3. Printed paper roll
4. Punching machine
5. Finished blanks



Fig. 8: Paper cup machine,
Weyhmüller Verpackungstechnik GmbH, 2024

Production of Paper Cups in the Cup Machine

1. Die-cut and printed blanks are placed precisely in the cup machine's magazine to ensure a smooth start to the manufacturing process.
2. The individual blanks are pulled from the magazine into the machine, then placed and fixed around a conical mandrel.
3. The ultrasonic sonotrode moves downwards, welds the longitudinal seam and the conical cup sleeve is created.
4. The cup sleeve is rotated 90° vertically and placed in a mold cavity located on a rotary indexing table.
5. The die-cut cup bases are fed in and placed in the cup sleeve. A precisely fitting mandrel pushes the base downwards inside the conical sleeve.
6. The base of the cup is welded to the shell to create a permanent connection between the base and the shell. The lower part of the sleeve is folded inwards to secure the bottom. The lower part of the jacket is often moistened with water or preheated before folding.
7. The top edge of the cup is rolled up to eliminate sharp edges and prevent injuries when drinking.
8. Once the process is complete, the finished cup is automatically ejected from the machine and is ready for use.



Different Processes for Welding the Base and Shell

Machine manufacturers use various welding technologies and tools to weld the base of the cup to the shell. The different welding processes are described below.

Welding with Hot Air

Welding with hot air is characterized by speed, a low number of wear parts, greater flexibility and environmental friendliness. Wear parts are required to produce different cup sizes (different cup diameters) on the same machine. The cup or nozzle can simply be moved axially. This means that different cup lengths can be produced without changing parts, offering additional flexibility. Compared to welding with a gas flame, welding with hot air is more environmentally friendly because no carbon emissions are produced. Compared to other processes such as welding with infrared heaters or heating coils, hot air welding requires less energy for the same machine capacity, which conserves natural resources and saves costs.

If recirculating air heaters are used to generate the hot air, this results in considerable energy savings as the hot air can be fed back into the process. This underlines the sustainability of this technology. Avoiding oxidation during the welding process guarantees the consistently high quality of the weld seam. The temperature and air flow can be regulated as per individual requirements, enabling precise process control.

Welding with Infrared Heaters

Infrared welding is another method. The choice of material and the wavelength of the infrared heaters are decisive for process efficiency. The success of this process greatly depends on how effectively the material absorbs infrared radiation. This procedure is very form-specific. This means that when changing to a different cup diameter, the infrared heater must also be replaced and readjusted. It should also be noted that infrared welding is slower compared to other joining technologies.

Welding with Gas Torches

Welding with a gas torch is known to be a fast process, but there are some challenges to consider: The very high temperatures can lead to potential burn marks on the product, impairing the product quality. In addition, the weld seam is susceptible to oxidation due to the high temperatures, which can also lead to a loss of quality. Another aspect is the challenge of precise gas flame regulation. In addition, using gas always means increased safety requirements for the working environment of the machines and for the operating personnel due to the risk of explosion.

Welding with Heating Coils

Welding with heating coils is a cost-effective method as they are available worldwide relatively inexpensively. However, this cost-saving option comes with some restrictions: Compared to more precise welding methods, welding with heating coils offers only limited accuracy and less energy efficiency as the heat radiates to all sides of the coil. Another disadvantage is the lack of control of the welding technology. The limited options for fine-tuning and control during the melting process can lead to unwanted fluctuations in the quality of the weld seam. This process is also slow and is therefore only suitable for low-cost, low-capacity machines.

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Advantages and Disadvantages of the Various Sealing Processes

Criteria	Hot air	Infrared Heaters	Gas Burner	Heating Coil
Precision and controllability	++ very good	+− medium	+− medium	−− poor
Uniformity of heat distribution	++ very good	+ good	++ very good	−− poor
Speed of welding process	++ very high	+− medium	++ very high	−− low
Energy efficiency	++ very good	+− medium	+− medium	+− medium
Environmental friendliness (carbon emissions)	++ very good (if green energy used)	++ very good (if green energy used)	−− poor	+− medium
Investment costs	+− medium	+− medium	+− medium	++ low
Occupational safety	++ very good	+ good	−− poor	+ good
Maintenance effort	++ low	++ low	−− high	++ low
Cost efficiency during operation	++ very good	+− medium	++ very good	++ very good
easy adaptation to new product or different board thickness (presetting)	+ good	−− complex	−− complex	−− complex

7. Conclusion

Cardboard and paper-based packaging protects food from external influences such as air, moisture and light. It helps keep food fresh for longer and extend its shelf life. There are many types and applications of this packaging.

In addition to coating, printing and cutting, numerous welding and sealing processes also play a decisive role in the production of cardboard and paper-based packaging. These processes are of key importance for food safety because the packaging must be strong and tightly sealed.

Sealing with hot air is precise, safe and environmentally-friendly, and it offers numerous advantages over other processes. Switching to hot-air sealing does pose challenges for machine operators: greater space requirements and higher electrical energy consumption. These challenges can be successfully overcome by using modern heating technologies and innovative air heaters, however. Carbon neutrality, easier adjustment of the process parameters and better sealing quality also have a positive effect here. Important to know: existing machines can easily be converted from gas to hot air.

To sum up, hot air sealing of cardboard and paper-based packaging is an innovative and sustainable solution that meets the increasing demands for quality, efficiency and environmental friendliness in the food and beverage industry. This is because sealing coated cardboard or paper-based packaging materials with hot air works very well even with high machine capacity and low cardboard coating thickness. The weld seam produced is of high quality, which facilitates reliable operation. In the meantime, technologies have become available to operate air heaters efficiently and with minimum resources. Here, hot air recirculation plays an important role in keeping operating costs down and using the machines sustainably.

Machine manufacturers are therefore advised to equip machines for the production of cardboard and paper-based packaging with hot air systems and to use air heaters capable of recirculation.

In view of current and future sustainability and environmental requirements, machine operators are well advised to use hot air for sealing cardboard and paper-based packaging. In this way, they will continue to meet the requirements of their demanding customers in the food industry in the future.

Sources

Image Sources

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Figure 1	Tetra Pak, 1950 www.tetrapak.com
Figure 2	Tetra Classic shop window, Tetra Pak 1957 www.tetrapak.com
Figure 3	Production of the paperboards (packaging material), SIG Combibloc, n.d. www.sig.biz
Figure 4	Schematic representation of the roll-fed process, packaging (folding and sealing) and filling take place within the machine. Professional Association of Cardboard Packaging for Liquid Foods. V (FKN), n.d. www.getraenkekarton.de
Figure 5	Filling machine for roll-fed method with loading station for packaging material roll, Tetra Pak, 2020 www.tetrapak.com
Figure 6	Filling machine, SIG Combibloc, n.d. www.sig.biz
Figure 7	Filling the prefabricated sleeves or blanks, SIG Combibloc, n.d. www.sig.biz
Figure 8	Paper cup machine, Weyhmüller Verpackungstechnik GmbH, 2024 www.weyhmueller.com

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