White Paper

E-Grocery Packaging of the Future

LOGISTIKUM RETAIL

UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

On behalf of Greiner Packaging International GmbH

and the TGW Logistics Group

greiner packaging

TGW LIVING LOGISTICS

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The results are part of the research project 'e-Pack' which was co-financed by the State of Upper Austria within the framework of the Excellence Network Logistikum.Retail.

1. Motivation and relevance of the research project

The research project "**e-Pack**" was initiated by the two internationally operating companies TGW Logistics and Greiner Packaging, both based in Upper Austria, and the research department logistikum.RETAIL at the University of Applied Sciences Upper Austria.

The aim of the project is to understand **how the unique characteristics of online food retailing affect packaging design**. Essentially, it is about figuring out what the primary packaging of products should look like in the future to meet the requirements of online retailing.

The need to address this issue arises from the following development: Over the last decades, the emergence of e-commerce has shifted a large proportion of retail sales from bricks-and-mortar stores to the internet. This has affected all retail segments, including food retail. The fact that regarding food retail, online penetration is not yet as high as in other segments is partly due to consumer reluctance, but also to the processes involved. As the **manual compilation of customer orders is very time-consuming and therefore cost-intensive**, and as it is becoming **increasingly difficult to find staff to carry out order picking**, there is a **need for a (partially) automated solution** on the retailer side.

The first providers of warehouse automation systems took this into account and started to develop picking robots. As robots are typically used in an industrial context where products are handled with comparatively insensitive materials, it is assumed **that products, or their packaging, could be damaged during the picking process or cannot be picked by the robot at all**. Given the **potential role of primary packaging in supporting robotic online order picking,** it is necessary to **assess whether packaging modifications are required** and, if so, what specific aspects need to be modified. In addition to the handling of a picking robot, during which the packaging must remain undamaged, this also applies to all further process steps until the order is received by the customer. In this respect, it should be assessed whether **damage to products during the so-called last mile** happens due to "bad" primary packaging and/or whether it can be **avoided or reduced by using packaging that is adapted** to the specifics of the last mile handling.

2. Developments in Online Food Retailing

While online retail in general accounts for a large proportion of total retail sales [1] this does not (yet) apply to the category of food [2]. Although it was assumed that online food retailing would become as important as in other product areas, this has not yet happened. This might be due to several reasons. For example, additional delivery fees, high minimum order values and inflexible or excessively wide delivery windows [3]. Consumers also have concerns about the quality of fresh produce (e.g., degree of ripeness of fruit and vegetables, comparatively short best-before date) and therefore prefer to be able to check this, including making their own selection [4]. On the other hand, convenience in the form of unlimited opening and ordering times, as well as home delivery and, in some cases, a larger selection are appreciated [3].

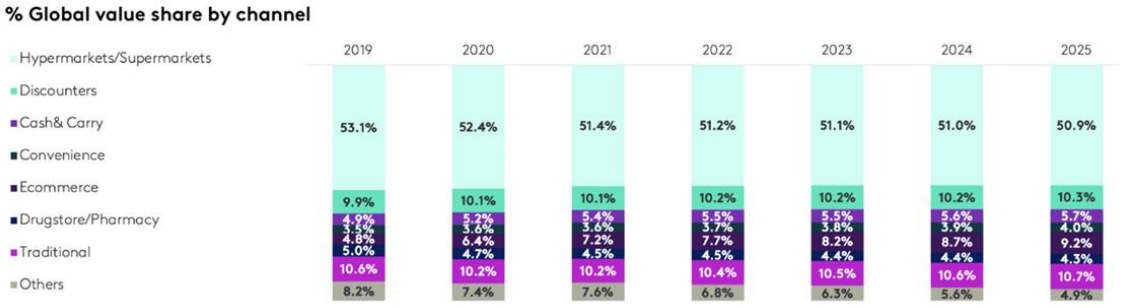

Figure 1: FMCG sales distribution by sales channel [5]

Globally, online sales account for 8% of total FMCG sales 8% [5]. In a continental comparison, Asia stands out, where the figure is about twice as high [5]. In Europe, on the other hand, it is below the global average and amounts to about 4% for the EU-15 [6]. Looking only at food, the online share is lower and amounts to less than 2% on average in Europe. In addition, it can be seen that the online share (for FMCG) in large cities is higher than the national figure (e.g. in 2021: Berlin 7.5%, Germany 3.7%) [7]. One possible explanation for this is that the majority of online shoppers are younger [3] and that they live in (large) cities more often. Furthermore, the delivery regions of most retailers do not cover the entire country, but so far only certain (test) regions and these are usually (large) cities [8, 9].

Online shoppers make an average of ten purchases per year globally. The products most frequently purchased online are cleaning products, personal care and hygiene articles, pet food, and long-life foodstuffs [10, 11]. Online shopping is particularly useful for (re)purchasing bulky or heavy products as well as stock products [10]. However, traditional weekly shopping has not yet been widely replaced by online shopping.

The "advantage" of online food retailing is that it is developing more dynamically than brick-and-mortar food retailing [12]. While the FMCG market has only seen slight growth in recent years, the online sales channel has achieved double-digit growth rates. Growth in 2020 and 2021 was boosted by the coronavirus crisis [6, 13]. In the subsequent year, growth was minimal and is now following a similar trend to the period preceding the coronavirus outbreak. The Ukraine war and the high level of inflation that has prevailed since then have slowed down development additionally [14, 15]. As a result, many consumers are paying more attention to price [16]. Where (which channel, which retailer) purchases are made depends on the offers. Additionally, it has been suggested that comparing prices is easier when shopping in-store, leading to a more conscious perception of shopping expenditures. Furthermore, individuals may restrict or altogether avoid the consumption of non-essential products [16, 17]. For example, this applies to alcohol, chocolates and other specialties, which are among the product groups most in demand online [17, 18]. The future growth of online grocery retail depends on how existing retailers and new market entrants modify or enhance their offerings, as well as on external factors such as inflation or potential extensions of store hours.

Studies have shown that **online shoppers** are **more loyal** than brick-and-mortar shoppers [6]. Furthermore, their shopping baskets contain **more branded products.** It has also been observed that the brand share of previously stationary-only shoppers is also higher when shopping in stationary stores after starting with and then continuously shopping online [19].

3. Players in Online Food Trade

Retailers active in the online food trade can be divided into two categories. First, retailers that **only operate an online store (pure e-supermarkets)** and second, retailers that sell their products **via both brick-and-mortar stores and an online store (clicks & bricks)** [7].

Regarding the fulfillment of orders, it is important to differentiate between Click & Collect and delivery. Click & Collect allows customers to pick up their orders at a specific time, after the provider has collected the goods. Collection locations are typically limited to specific stores operated by the retailer [20]. This means that collection is limited to the opening hours of the location. In most cases, the order is delivered to the customer by an employee. In some cases, however, there are also pick-up boxes (similar to a postal package pick-up station) where customers can pick up their purchases at flexible times [21].

While **customer orders** at Pure E-Supermarkets (e.g., Picnic) are only **compiled via central warehouses**, Clicks & Bricks (e.g., Hofer) **sometimes also do** this **via stores**. With store picking, the

items are usually taken from the stock on the shelf. Depending on the delivery model, this is carried out by our own employees or the employees of the respective cooperating Quick Commerce service provider (e.g., Wolt). Retailers that process order picking via a central warehouse still sometimes rely **almost exclusively on manual picking (e.g., Billa) [22]**.

Regardless of how the customer orders are put together, the next step is delivery to the customer. This is done either via our own fleet or by outsourcing to a service provider.

4. Changes Along the Supply Chain with Significance for Packaging

The traditional supply chain process from the manufacturer to the end consumer typically involves two to three intermediary steps [23]. The manufacturer delivers the goods (usually on pallets) to the central warehouse, often also called the logistics center, of a food retailer [24]. There, the pallets are brought to the designated storage location and the shrink wrap applied to support stability is removed. To assemble the store orders (if manual picking is involved), an order picker with an electric pallet truck carrying a pallet moves to the storage locations of the items on the pick list one after the other. The order picker takes the number of cartons specified in the pick list from the storage pallet and places them on the picking pallet. Once the picking process is complete, the store pallet is shrink-wrapped again to ensure stability. All packed pallets destined for the same store are transported to the store by a truck. In the store, the pallet is moved with a small industrial truck ("e-ant"), i.e., a store employee drives to the shelf locations of the items on the pallet and places the cartons on the shelf (for discounters; for full-range retailers, the individual items are placed on the shelf without outer cartons). In the store, the customer removes the desired products in the respective quantities. Once payment has been made, the customer takes the items home themselves.

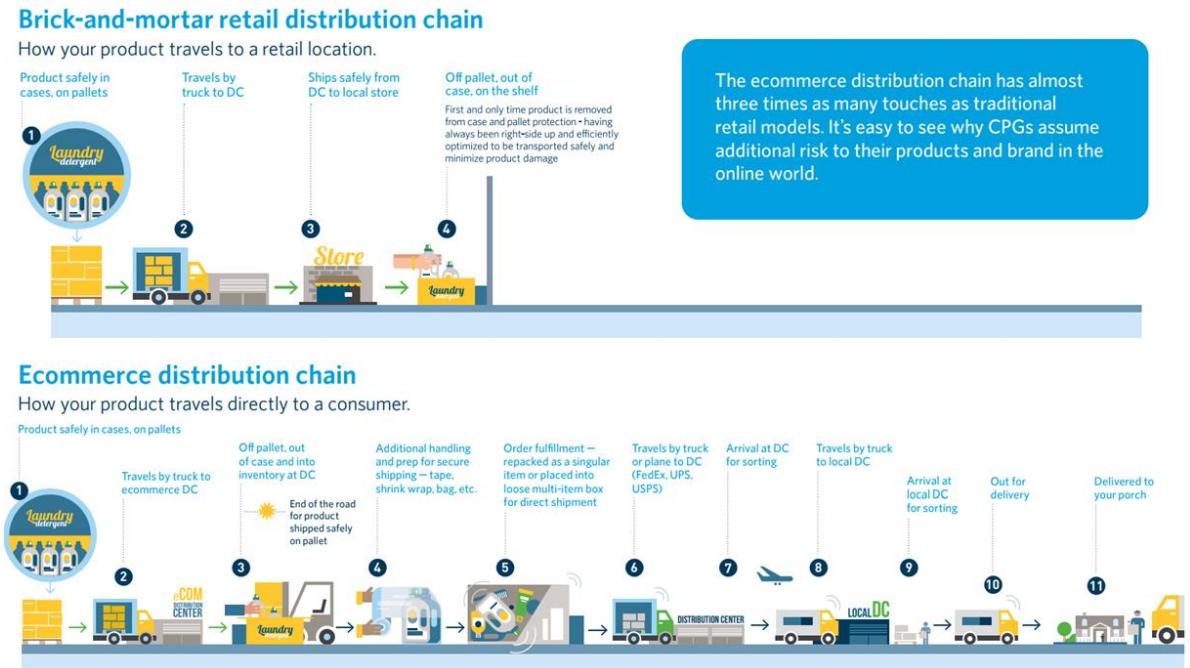

Figure 2: Supply chain in brick-and-mortar retail and in e-commerce [23]

The process just described has been modified for online retail that is handled via a central warehouse [23]. In this regard, it should first be noted that there are retailers who operate their own central warehouse for the online store's goods [25] but there are also retailers who process the online business via the same central warehouse(s) as for the stores (in a separate area). The shrink wrap is also removed from the pallets delivered by the manufacturer to the central warehouse. However, the goods do not remain on the pallets at the storage location, but the cartons or individual items are

moved to the storage rack. The picker again goes from item location to item location with his pick list, but this time removes the required number of items rather than cartons. The items are packed (often in bags) for each temperature range (dry, chilled, fresh, and frozen). In order to avoid product collision or damage, filling material is often added for protective padding. The finished bags, which require a certain temperature range to be maintained, are stowed in various boxes with cooling elements or insulating properties for delivery. The bags are handed over to the customer by the deliverer without the box.

As the description of the two process variants shows, there are **two key differences between traditional retail with brick-and-mortar stores and online retail with** home **delivery** [26]. First, **the product handling of the individual item without tertiary (pallet incl. shrink wrap) or secondary packaging (outer carton or tray carton) takes** place at an **earlier stage**. This means that the individual product is less well protected against mechanical stress/influences. Second, **the customer** is in possession of **the products at a later point in time**. While the customer is responsible for transporting the product home in the case of independent in-store purchases and therefore bears the risk of damage from the time of payment, this is the responsibility of the retailer in the online business.

5. General Packaging Trends

Currently, there is a widespread focus on the use of recycled and sustainable materials, as well as reducing the number of materials used in rigid plastic packaging.

Figure 3: Bucket with grid structure [27]

Examples of corresponding new packaging developments or optimizations include packaging made of monomaterials (especially PET), mesh buckets (material cut-outs) [27] bio-based plastics made from raw materials such as oranges [28] and corn or dark-colored containers made from plastic waste collected in the oceans [29].

New packaging developments and optimizations regarding e-commerce mainly come **from the D2C sector** and relate to **orders that only include one product**. The **primary and secondary packaging of a product** are **combined**, **thereby saving packaging material**. The phrase "ships in own container" (SIOC) is often used for this purpose [30].

Figure 4: Detergent in Bag-in-Box-packaging [31]

One example of such packaging changes are cleaning and detergent products that were previously packaged in large plastic bottles [31]. These were converted to the so-called bag-in-box packaging system (a plastic bag with a tap inside a paper carton), which is more familiar for wine or juice. In addition to the reduced use of materials (especially plastic), another advantage is the elimination of the risk of breakage and thus leakage.

However, the corresponding product variants are only used for online sales, but not for sales in stationary stores, where the plastic container is still used. For Clicks & Bricks retailers, however, it will not be acceptable to have two (packaging) variants of what is otherwise the same product, partly because a large number of products are already on offer. As the two variants are considered distinct products, there is a corresponding need for data maintenance and a risk of confusion. As a result, the minimum order quantity required by most suppliers must also be purchased for both products. It may then be necessary to order (more) goods than would otherwise be required. Other associated disadvantages may be higher purchase prices, as graduated prices are granted separately for a higher quantity per product, or remaining shelf-life problems due to higher inventory levels.

Since the stationary business accounts for the majority of sales, product packaging design will be tailored to meet its requirements. In this respect, manufacturers find themselves in a dilemma if both Clicks & Bricks and pure e-supermarkets are among their customers. While retailers specify how the packaging should be designed for their own brands [32] and the manufacturer has to adapt, the reverse is true for branded products. If the retailers want to offer branded products, they have to accept them as they are offered by the brand company. Typically, brand manufacturers design packaging with retailers in mind, aligning with their requirements. When a branded goods manufacturer serves both pure e-supermarkets and Clicks & Bricks, they prioritize the customer segment contributing more to sales or turnover. In this respect, it is relevant for packaging manufacturers to observe developments in the (online) food retail landscape to proactively have appropriate packaging optimization proposals up their sleeves in the event of relevant shifts in favor of e-commerce. If it is known from which manufacturers the e-pure supermarkets purchase their own-brand items, correspondingly optimized packaging can be developed for them. This allows the respective packaging manufacturer to stand out from competitors who have not yet made any efforts in this regard.

6. Warehouse Automation – Picking-Robots

The **manual picking process** described above has been **increasingly** replaced **by automation solutions in** recent years [33]. In many cases, the central warehouse is now almost fully automated (e.g., Spar warehouses in Wels and Ebergassing [34]). In most cases, however, the solutions are limited to store picking, i.e., based on cartons. One reason for this is that the online food business still accounts for a small proportion of sales for Clicks & Bricks, especially in most European countries. For them, an innovative automation system with correspondingly high investment costs would (currently) still generate too little revenue. On the other hand, **online grocery retail** has a few special features that push **classic industrial robotics to its limits.** In this regard, there is currently a lack of mature solutions optimized for online grocery retail available on the market. This is due to the **large variety of** articles [35] and the often **unstable or sensitive materials** that make up food and the packaging in which it is contained [36]. One food product category whose associated items require **particularly careful handling** is **fruit and vegetables**.

Traditional (industrial) robots were designed for the use of similar objects [37, 38] that do not require "gentle handling". Accordingly, **end-of-arm tooling is made of rigid materials**. **However,** these are **hardly suitable for FMCG products**. Alternative, fairly new solutions come from the field of **soft robotics**. The robots designed there can adapt **to the shape and size of different objects**. This flexibility is made possible in particular by grippers made of **"soft" materials** such as polymers, elastomers, hydrogels and hybrids [39].

Thanks to the possibilities of soft robotics, the first models of so-called **pick robots** now exist. The **key elements that** enable them to meet the special requirements of online grocery retail are **precise cameras**, **gripper/end-of-arm tooling** and **a** system **based on machine learning** [40].

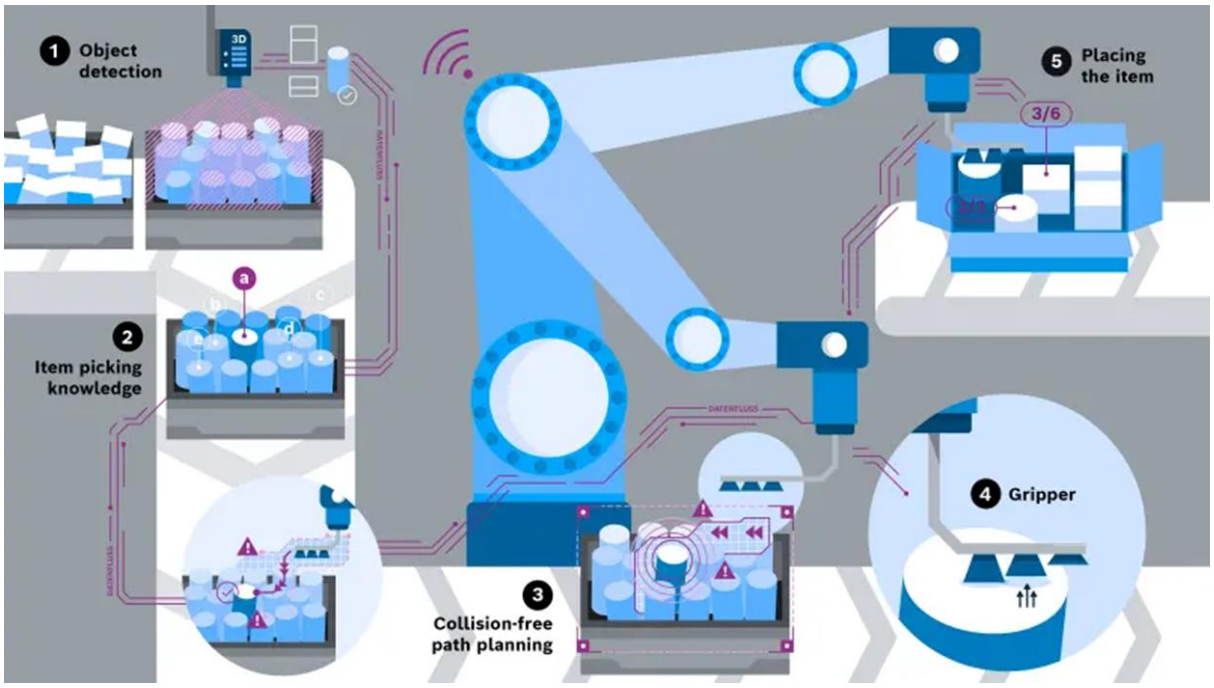

Figure 5: Typical picking process sequence [40]

The basic process for fully automated single-item picking with picking robots is as follows: the source tote containing all the items in a customer order is brought to the location of the picking robot via a conveyor belt-like system. There, the products are detected by the cameras located above the source tote and the ideal gripping position and strength are determined "in the background". The robot arm then moves to the corresponding product, lifts it and then places it in the target tote [40].

End-of-arm toolings with suction cups made of silicone or other similar soft materials are currently mainly used for gripping or lifting products [41]. Previous experience with such picking robots shows that certain products can be handled easily, while others still present difficulties. With very small products, for example, it is difficult for the robot to recognize them in the source tote. The same applies to transparent products (e.g., shower gel in a transparent plastic bottle). With large-volume items, a central gripping action is crucial to ensure that the suctioned product does not develop too much momentum due to the movements in the "floating transport process", causing the suction cup to come loose and the item to fall down. There are also products that are completely non-suckable, such as loose lettuce, and products that are difficult to suck. The latter includes products with an uneven surface.

The key **performance indicator is** the **pick rate per hour**. This indicates the number of items picked in one hour [37]. Values for this can be found from individual providers; and usually range around 1000 articles per hour (e.g., Swisslog ItemPiQ) [42]. Robots were originally designed and developed to increase productivity. However, there are at least two other reasons for using them. One is that employees should be relieved of physically demanding tasks and instead be used for other activities. Secondly, due to a worsening shortage of employees in certain industries - including logistics and warehousing - there is a need to find alternative ways to ensure that certain tasks can continue to be carried out.

In general, in addition to output, costs are a key criterion in deciding whether to make an investment. This also applies to picking robots. However, no information on costs can be found in the documentation on the manufacturer's website. This suggests that they are (still) quite high - as is usual for innovations. Together with a possible uncertainty as to how such a robot can be integrated into existing processes and to what extent it will create benefits in the company, this explains **why the use of picking robots has so far been the exception in practice**. Even if there is an overall lack of transparency as to which (food) retailers active in the online business use picking robots, the few references cited by the providers suggest that **e-pure supermarkets have a greater interest in them**. Examples include Picnic and Frisco. It is to be expected that **costs will also fall with increasing distribution**. It is very likely that this will materialize, as **the expected savings are not insignificant**.

7. Significance of the Last Mile

The changes in the supply chain can pose **challenges, especially on the last mile**. This is particularly true if the retailer **outsources the home delivery** step **to a service provider**. In this case, the retailer has **no influence on the care with which** the parcels (= the delivery/shipping packaging for the products combined into one order) are handled. Processing via classic CEP service providers is particularly critical, where the parcels are sorted in a distribution center according to the route planning of the delivery vehicles after delivery or collection, i.e. there is still an intermediate step here in which negative influences can occur [43].

Figure 6: Deformed dairy products [44]

In the case of some groceries, "intensive" movements (e.g., abrupt braking or energetic loading into the delivery vehicle) can cause them to collide with other products or the shipping packaging, resulting in **deformation of** the product packaging and possibly the contents or **damage** to the primary packaging. An example of this is the collision of two products in glass, which can result in breakage. Packaging with sharp corners or sharp edges can cut into other packaging. In the case of liquid contents (e.g., milk or strained tomatoes), **leakage** not only renders the damaged **product itself unusable or unconsumable**, but also contaminates one or the **entire** other part of the **order** or, if paper or cardboard packaging (e.g., pasta) is soaked or softened, contaminates the contents of other products.

However, not only intensive, but also "incorrect" movements in the sense of turning movements or inverted position can have a negative impact on a product. If cheese slices are positioned sideways or vertically instead of horizontally, they slide together and form a lump. A head of lettuce that may be on heavier items is irreversibly crushed by even a brief rotation.

CEP service providers only offer guaranteed careful handling for a very high surcharge (e.g., declared as fragile content or dangerous goods) [45]. In addition, these are more likely to be regarded as generalist deliverers, as no special vehicles with special features (e.g., **refrigerated temperature control**) are used as standard. If products therefore need to be cooled, this must be ensured by other means, e.g., by using special containers with insulating properties and/or additional coolants [46].

8. E-commerce relevant Optimization Approaches

8.1. Last Mile

In principle, **packaging** must fulfill **several functions.** Packaging acts as an **information carrier,** which is particularly true for primary packaging. However, the **relevance of this is reduced in e-commerce,** as the consumer has already decided on a product. The information provided for this and therefore the basis for comparison/selection and purchase decisions are product descriptions and possibly images. The latter often show the contents and not the packaging. On the other hand, the secondary packaging is of greater importance, as the **unboxing experience has a** significant influence on satisfaction with the provider and, as a result, the likelihood of repurchase. The unboxing experience begins with the assessment of the condition of the secondary packaging. What counts here is that the **packaging does not** appear **damaged** or has been opened. As an online retailer, unless you use your own logistics, you have no control over the care taken in the last mile, so the only way you can control how the order reaches the customer is through the packaging used.

Perhaps the **central function of packaging in online retail is** product **protection** [47]. The customers of an online store expect the goods they order to arrive in an undamaged condition [48]. While deformed primary packaging "only" looks unattractive, the consequences of other packaging damage are more serious. For example, broken, torn or otherwise opened primary packaging can cause the contents to leak (e.g. detergent leaks) [23], which may mean that the other products in the order can no longer be used. However, this also means that the product can no longer be used (the detergent in question can no longer be filled into the washing machine).

To avoid such damage from the outset, the products should be adequately packaged. In many cases, only secondary packaging is considered. However, the packaging of individual products can also be used to optimize their stability and protection.

Laboratory tests that simulate the influences of the last mile are a starting point for identifying which products need action. The best-known method is the ISTA Type 6 standard, which determines the

ability of parcels and products to withstand the shocks that typically occur during handling in transit [49].

Another option may be to carry out test orders. The advantage of this is that you can see the condition in which the products arrive or any damage they show.

Similar insights can be gained from customer feedback on online orders. It is difficult for packaging manufacturers to gain this insight; they rely on input from online retailers. The extent to which they share or pass on relevant information is one factor, but the fact that customers provide feedback at all is another.

Regardless of how such optimization-relevant ideas are obtained, they must be treated with caution. Little importance is attached to the fact that several products are combined into a complete package and thus limitations arise, for example, from the fact that every order is different. This means that even with the same external influences, the interaction of the products in the secondary/shipping packaging is different.

As a rule, **products have so far been designed to meet the requirements of physical sales (in stores)**. Many products are therefore designed in such a way that they stand out on a shelf in a store, e.g., due to their extravagant shape. Products that are sold online do not need eye-catching packaging as the buying decision has already been made. There is no need for "impractical" shapes or additional packaging elements. In terms of **shape**, the recommendation can be **cubic**.

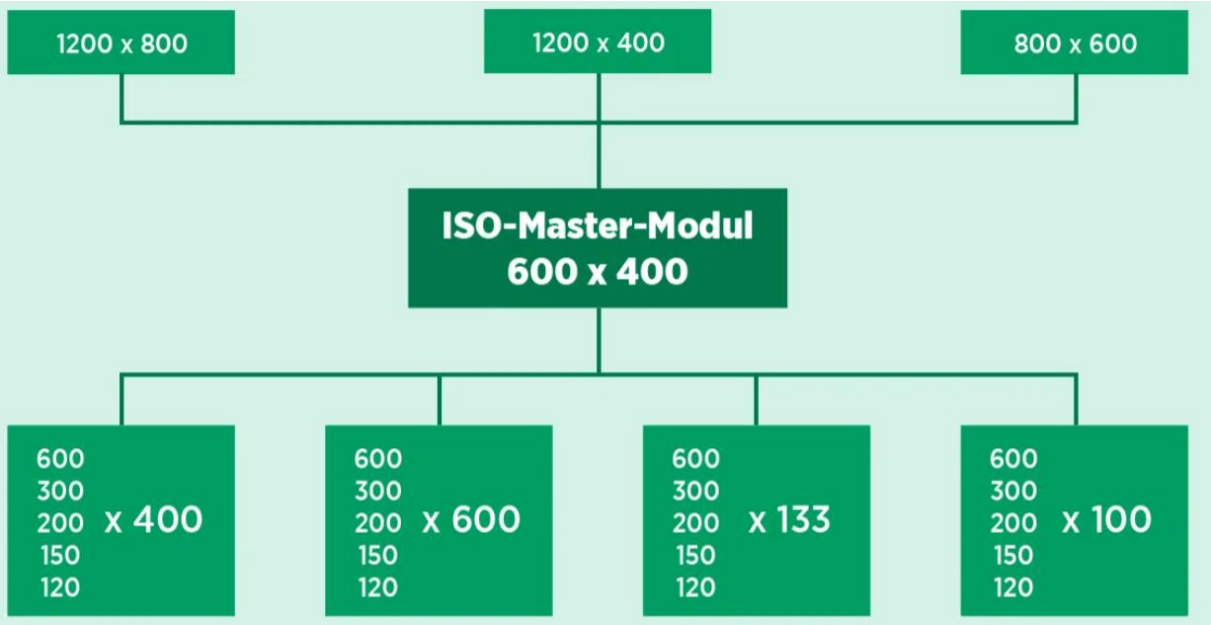

Figure 7: EUL-Basis Dimensions for Secondary Packaging

This can be justified with reference to the current **transport and packaging standards** and formats, which are designed for **efficient handling** in terms of **(freight) space utilization** [50]. If round or cylindrical packaging is converted, more content can be filled in with the same packaging volume consumption or less packaging volume is required for the same amount of content. This in turn affects the size of the shipping packaging. The situation is similar with the type of packaging material and the packaging weight. If heavier packaging materials are replaced by lighter ones, the overall weight becomes lighter.

With regard to secondary packaging, **filling material** is often simply added to **fill empty spaces**. However, this can be dispensed with if the packaging is adapted to the volume of the order contents

("**customized packaging**" or also fits to size packaging) [51]instead of using a standardized carton size or selecting fewer sizes from the portfolio.

Figure 8: Packaging of the Picnic own-brand muesli [52]

The e-pure food retailer Picnic has relaunched the design of its own-brand products. One of the reasons for this is that customers have already decided on a product or brand online, so there is no need for generic information such as product names at the point of sale, and there is an opportunity to highlight individual products. A separate but related innovation is the animation of product images in the online shop - for example, the ears of the rabbits that adorn the toilet paper packaging wiggle. On the back of the packaging, in addition to product details (in four languages), there is a QR code that customers can scan to order refills directly from the app [52].

Figure 9: Carton cutting machine for flexible packaging sizes [51]

For the use of cardboard packaging, for example, there are corresponding systems that cut the cardboard to size individually. The use of the **smallest possible packaging size** should also be aimed for, as most **CEP** service providers do not offer their **service** on a piece basis, but usually according to size-weight **requirements**. Smaller packaging can therefore **influence costs**. In addition, smaller packaging means less packaging material is used, which in turn also has a positive monetary impact. However, filling material is not only used to fill empty space, but also for **padding**. It would be possible to forgo this if the primary packaging is sufficiently stable. **Greater stability** can be achieved by using **more material**, **substituting the previously used material** with a different one, or changing the material composition. Material savings can be achieved by dispensing with padding material, especially when using more primary packaging and considering the total packaging requirement and consumption.. Consideration should also be given to whether greater stability or better product protection can be achieved. Overall, it will be difficult to determine which overall packaging element (primary or secondary) has the greater effect in terms of stability or protection.

Another consideration is the cost of the optimization. Particularly in the case of primary packaging optimization, it is important to consider whether the additional cost is lower than the cost of disposing of an individual product due to damage (i.e. some loss in the purchase price of the product).

As product protection is crucial, packaging plays a vital role. However, packaging, especially plastic, is often criticized for being unsustainable. Therefore, it is essential to provide consumers with accurate information. For example, it should be addressed that **packaging counteracts food waste**, because if food is not packaged, its shelf life is greatly reduced. The use of materials for packaging has **fewer** negative effects or is associated with a lower use of resources than the **"loss" of food due to** spoilage [53].

8.2. Pick-Roboter-Handling

Currently, the picking robots available in the market face difficulties in handling several types of food products. Nevertheless, in order to ensure robotic picking, one possible solution is to optimize packaging for this purpose, e.g., by adapting the design. The starting point is therefore the **requirements of the robot**. In line with the currently most used gripper solution(**suction cups), it must be ensured** that the **surface** is smooth. Furthermore, multi-part packaging parts that are not firmly connected to each other should be avoided, as these could otherwise detach during lifting or due to rapid movements. One example of this is the Snap-on lids on yoghurt pots, which are intended to be resealed after initial opening. Such conversions in the packaging sector may be quicker to implement than improving robot skills. However, there are also hardware-side possibilities for robot optimization. For example, different sized suction cups can be used to accommodate products of different sizes and weights. However, these must then be changed depending on the product. Ideally, this can also be done automatically, i.e., by the robot itself. In principle, this can be achieved with appropriate adapter attachments [54]. The disadvantage here is that the replacement is time-consuming and therefore less efficient.

Figure 10: Picking vegetables with soft gripper

The solutions described above are not suitable for the majority of **(unpackaged) fruit and vegetable products.** A **different type of end-of-arm tooling** to suction cups could be used here, namely**finger-like grippers [55]**. Due to the sensitivity of the items, they should also be made of a soft material. As finger grippers are a less universal handling option (the products must fit between the fingers, which means that the range can only include products of a certain size), they should at best be seen as a supplement to the suction cup. If a finger gripper is (additionally) used, the amount of products that are problematic for picking with a suction cup reduces significantly.

Figure 11: Adapter for Dual-End-of-Arm-Tooling [56]

Instead of the previously described **change of end-of-arm tooling,** a combined solution, i.e. **dual end-of-arm tooling**, would be optimal [56]..

However, consideration should be given to the extent to which it is necessary for all products to be picked by a robot. This is not only a question of (technical) feasibility, but also of the cost-benefit ratio. Particularly in the (still) challenging product category of fruit and vegetables, there are two further points to consider in addition to the ability to be picked. Firstly, they are often stored chilled and may also need to be delivered at a controlled temperature, which requires segregation from the rest of the products in the order from other temperature ranges. Secondly, separate packaging or separation from other products may also be required as they must not be loaded with other weights so as not to change their condition (easily deformed). Both would require a two-part process anyway, so it seems more reasonable to utilize and combine the strengths of each actor (human picker and robot).

9. Results of empirical pick tests

On Tuesday, 6 November 2023, the project team from the three before mentioned institutions visited the TGW Logistics site in Rohrdorf, Bavaria, which specializes in robotics, to carry out on-site picking of various products selected by Greiner Packaging. The goal was to determine where problems exist and subsequently derive approaches for optimization. A key observation was that the robot's gripping ability was very good, i.e. the picking robot did not struggle with the gripping ability of almost any product. It was also noted that some of the products sent in parcels arrived damaged. From this it can be concluded that of the two process steps, order picking and last mile transport, the latter is the bigger problem area and therefore needs to be looked at more closely.

For products in buckets, it has been found that the moveable handles get caught up with other products, so they should be fixed or omitted. (Re-closable) lids that are only clipped on may fall off beforehand or come off when gripped, causing the product to fall. The lid should therefore be clipped on or left off.

Foil or cardboard labels may come off the product if they are only clipped on or have only a few adhesive dots. This means that they should be stuck to the product with their entire surface, if possible, or the packaging should be printed instead.

Figure 12

As the robot tries to grip products in the middle, the packaging should not be uneven, especially there. Otherwise, the robot will try to grip off-center, resulting in uneven weight distribution and a less secure grip.

Figure 13: Tall, narrow, cylindrical packaging

In terms of shape and height, tall, narrow packages can be more difficult to handle as they are more likely to fall over, altering the intended standing position. This is particularly true of cylindrical packages, as these move (roll) when lying down, making gripping less precise and possibly impossible.

The safest and most reliable gripping is achieved with products that are cubic in shape. Rectangular items where the side lengths do not vary greatly are also good. In addition, the top should be straight, not slanted, otherwise precise gripping will not be possible because the robot arm will only operate in a vertical position, not in an angled or slanted position.

10. Expert interviews

Expert interviews are considered a valuable approach for gathering insights into a topic that is not well-discovered and also when it comes to information that is not publicly available. Because of this, interviews representing two perspectives, grocery retailers and food producers, were aimed to be integrated into the research project. Despite intensive efforts to recruit experts, only three interviewees could be found (see table 1). Thus, only the retailer perspective could be portrayed, although it was originally planned to evaluate the producers' view as well. The goal was to evaluate the current state of order picking and packing, and delivery as well as experiences with damages due to poor primary packaging. In addition to this, because secondary packaging was found to be an important influencing factor and a provider of specialized secondary packaging agreed to interview participation, the scope of the interviews was extended. Overall, important information could be gained from three interviews. They lasted on average around one hour and were based on an interview guideline.

Table 1: Overview of interview partners

Company name	Interview partner	Position	Type	Order delivery mode	Secondary packaging	Order picking mode	Country
Nemlig	Frederik Andersen	Logistics partner	Pure online grocery retailer	Own fleet (small vans)	In fulfillment center and van: stable plastic boxes; for customer: totes	Manually	Denmark
Unimarkt	Hannes Wartbichler	Head of IT and Business Organization	Store-based and online* grocery retailer (*online shop closed in 2023)	Austrian Post	Insulated boxes (+ cooling material)	Manually	Austria
Temprify	Nikolas Loidolt	Founder & COO	Provider of reusable stable plastic boxes for passive cooling	(customer decision, typically own fleet)	Stable plastic boxes (+ cooling material)	-	Austria

Key insight 1:

The first key insight shed light on the composition of customer orders. The **average basket** consists of **products from different temperature zones**, but they **can't be packed together**. This means that the products have to be packed separately. Thus, a customer ordering fresh fruit, ice cream, yogurt, and canned beans gets (at least) three boxes or totes. For customers, this might be confusing. At Unimarkt, fresh fruits and vegetables that do not have to be cooled are packed together with the cooled or dry products depending on the free volume of the package. If the outer temperatures were quite high in summer, this also influenced the decision of where they were put. For some products like bananas, the right temperature window is important because if too high they ripen fast and if too low the peel becomes brown which isn't very appealing.

Frozen products have the **lowest share** of the three temperature zones. For retailers, it would be beneficial not to offer them because of the high costs. But they can't abstain from it as **customers expect a whole variety of products**. Both Nemlig and Unimarkt said that **one of** their **best-selling products** is **banana**.

Key insight 2:

The second key insight illuminated the fulfillment of the picking process at both retailers and their perceptions of automation at distribution centers dealing with groceries. At Unimarkt and Nemlig the **picking and packing is done manually**. Nemlig and Unimarkt stated that **picking robots should be able to pick all kinds of products** (and packaging types) and be able to check the best-before date. However, they cannot imagine that this is already the case. When it comes to automation of the picking process and checking the best-before date, they see challenges for the robot because the dates are often placed in different positions and cannot always be seen from front- or above-position. Unimarkt mentioned that for example for fruits and vegetables, their pickers are **checking the product quality** in terms of ripeness, etc. which they can't imagine that a robot will be able to do. For Unimarkt automating the picking of the online order fulfillment is not a topic of interest as the investment costs would be quite high and do not imagine them to pay off with the sales that are generated with e-grocery. Nemlig said that they could think about automation when it comes to building a new fulfillment center, but integrating automation in existing fullfullment centers is seen as a task to complex to be viable. Also, they argue that this would only make sense if the whole center were automated and not just parts. In terms of **optimizing online order fulfillment**, Unimarkt is constantly working on **improvements regarding the process**, and see most of the improvements in increasing task **standardization**. For example, they have implemented a packaging line in which one specific task is performed by one specific person. For example, a single worker is just responsible for closing the boxes.

Key insight 3:

Another topic that was treated and brought key insights was regarding product damages due to any type of packaging and other challenges related to packaging. Nemlig said that they don't have (or had) many issues with damaged primary or secondary packaging. They are facing **other/larger problems** like a varying emergence of customer orders or selling products with a short best-before date. To ensure careful treatment during the delivery, all drivers get instructions how to deal with the orders. Unimarkt, who operates stores as well, perceived that the online business causes additional costs and customers are not willing to pay higher prices for this extra service for the same products.

In general, as Nemling and also Unimarkt are **not the biggest players** in the grocery market, they **do not have much influence** on the producers and the packaging they use. The only thing they adjusted

is getting a private label branding for standard products like canned tomatoes. Thus, they have to accept or stick to what the other retailers have decided.

An issue with **secondary packaging** regarding the different basket sizes (due to a different number of articles and different article sizes) is the **dimensions**. When the orders are not delivered by the company itself, there is the need for adding filling material to ensure stability as a third-party company might handle it with less care. Also, as standardized packaging is used and either for one "left-over" product a larger packaging or a second package would be needed, it has a high influence on the delivery costs (or the fee that has to be paid to the postal company). When it comes to additional packaging, like filling material or secondary packaging, Unimarkt would like to use sustainable material, but as the cost for such material is high they still refrain to do so.

For Temprify, who offer **transport boxes with passive cooling**, a pizza carton was the basic product, which influenced the size of their box. They offer standardized boxes but also individual boxes (e.g., different dimensions). If a customer wants to have an individualized box, they have to order a certain minimum amount which is because of adapting the production lines. Temprify sees a large **benefit** in their solution because companies **don't need vehicles with different temperature zones**, so they are **flexible** regarding the composition of the different orders and can **use the space best**.

A challenge arises when **reusable secondary packaging** is used. When a customer is not at home at the time of the delivery, then, the postman either must come again or the package has to remain at the customer's place. This means that some actions have to be taken to **return** the secondary packaging **to the retailer**. Especially if the customer does not have to pay a deposit for the packaging, the retailer might not get it back at all. This is not only a problem because of the investment costs for the packaging but also is **crucial for having enough packaging resources to do new customer orders**.

Key insight 4:

Finally, the interview partners shared information on feedback from their customers and which changes/optimizations they made based on it. Unimarkt reported that they received **customer complaints about damaged products**. As they were relying on a third-party deliverer, it was not easy/not possible to figure out whose fault it was (them or the post). They did several **tests with different secondary packaging** and observed that **cardboard is the cheapest one**, but with packaging made of **other materials fewer product damages** do occur. The most issues they had were with **glass (e.g., for beverages)** and **products like yogurt in thin primary packaging**. For those, damages were observed when the package faced **much shaking**. Regarding the primary packaging, Unimarkt sees no need for optimization as the share of online does not stand for a remarkable share of the overall sales and the amount of/complaints on damages was on an acceptable level. Moreover, in the context of their stores, they have no issues with primary packaging.

Both Unimarkt and Nemlig said that they would not pay higher prices if a product had better primary packaging and as such would lead to fewer damages. They explained further that they would base the decision on a **calculation** in which the **additional packaging costs** are **contrasted with the costs for customer reward** (e.g., a voucher), etc.

When it comes to differences in the location (the place where to deliver), Unimarkt said that they did not have many orders from customers in Vienna. Their explanation for this is that there are other e-grocery players as well that have another approach to running online business. They offer a shorter **time** windows **for delivery** and also same day delivery (compared to Unimarkt's next day delivery if ordered until 3 pm on the day before). This **quicker fulfillment,** or in other words, **higher flexibility** seems to be **valued by the customers**.

Key insight conclusion:

Concluding, the interviews have shown that product damages due to primary packaging do occur, but it is not a big issue and thus there is no need to investigate this deeply. Instead, the delivery stage is the one that is most challenging because of the different compositions of order baskets (i.e., orders require different secondary packaging volumes and products from different temperature zones have to be packed separately). In addition to this, the automation of processes at fulfillment centers is seen as a relevant topic, but relying on picking robots would be only worth considering if they can handle all kinds of products and packaging types.

11. Conclusion and Outlook

Scientific research, as well as practical applications regarding primary packaging for e-grocery order fulfillment requirements, are currently in the **very early stages of development**.

On the practical side, there are several explanations for this phenomenon. Firstly, the volume of grocery sales through online channels remains relatively low. As a result, there are fewer businesses actively engaged in online retail, and those that are, **may prioritize addressing other pressing concerns** over optimizing packaging for e-commerce. For example, it is more critical for businesses to offer competitive pricing against other online players and to smoothly handle their inventory level. Overall, e-grocery retailers grapple with the repercussions of inadequate primary packaging, balancing the added expenses of packaging optimization against the losses incurred from damaged goods and subsequent customer refunds. Regarding the prevention of product damage, they perceive the **last mile/delivery as the most challenging step**. This is especially true when the delivery is outsourced to a third-party company, so they cannot control how the package is treated. Another challenge is that the whole basket has to be packed together, but as every order is unique and differs a lot from others, the use of standardized packaging is often suboptimal. As sustainability gets more and more important, some companies have done tests with **reusable secondary packaging**. However, achieving a closed loop is hard to realize as customers have to return the packaging and the packaging has to be prepared for the next delivery cycle which means extra effort. From the food producer side, there is also no need to investigate primary packaging optimization because of the small share of e-grocery retail customers. Also, producers often manufacture branded products and private labels. For both, typically the same packaging is used. The producers themselves would change it only when they would face problems with their branded product. Thus, the producers would only use a different packaging if the **production line would be able to handle another packaging** as well and if the private label company would pay for the additional costs of the packaging. Besides product protection, for brands, the marketing function of gaining the customers' attention and being different from competitive products of other brands is highly relevant.

The opinion of e-grocery retailers with fulfillment centers regarding automation is positive as this can help to deal with the lack of labor and reduce costs by increasing the effectiveness and efficiency of the processes. Currently, **especially pure online retailers perceive the investment costs to be too high** for them. In general, they can imagine automating their fulfillment center. As they find that this does not make sense for an existing building, they would consider it when they have to renew it. In addition to this, what speaks against the optimization is the downtime that would be necessary to do the installation and in which they cannot generate sales. Also, in their eyes, it would only make sense if the whole fulfillment center and not just parts are automated then. Moreover, they cannot imagine that a picking machine/robot can handle several products which would be their assessment to invest in such. Besides the doubt that not all products can be handled, manual pickers do quality checks (e.g., on the best-before date) which the robot potentially would also not be able to perform.

The use of **picking robots is not limited to picking online orders** in a central retail warehouse. They could also be used to store (overnight) deliveries of goods in a store. The counterpart to this is

removing products from the shelves and picking an order in this way. However, both cases require a different configuration of the robot and particularly its mobility.

Regarding warehouse automation, it can be observed and assumed that in the near future increasing automation will take place in order to reduce personnel costs and make processes more efficient. However, this will not be full automation, but rather the **coexistence of machines or robots and people**. Robots will support employees by taking over monotonous and/or physically demanding tasks or sub-steps in the overall process, while employees will be responsible for handling non-standardized products that require special care and will be involved in the robot-supported execution in a controlling or corrective capacity.

In terms of industry applicability, the use of picking robots in the online environment outside of food retail is even more likely and likely to add value due to the large variety of items with a wide range of packaging shapes, materials and sizes. In principle, there is a **wide range of applications for suction cup picking robots**, which are a relatively inexpensive and somewhat universal solution. This is because they can easily handle all (packaged) products with a smooth surface.

When designing packaging, it can be deduced that it should ideally have a closed, smooth surface and, if it consists of several parts, they should be firmly connected to each other.

Since in the e-commerce context not only the picking sub-process but also **the last mile has an impact** on the condition of the primary packaging, these aspects must also be considered when it comes to the initial development of new and optimization of existing product packaging that is suitable for e-commerce.

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