

SUSTAINABLE PACKAGING ALTERNATIVES: HIGHLIGHTING THE PROS AND CONS OF MATERIALS LIKE GLASS, METAL, COMPOSTABLE, AND BIODEGRADABLE OPTIONS

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Going through the grocery store, we will notice different types of packaging. We will find glass, metal cans, paper and a lot of plastic. Plastic packaging seems to be everywhere. Looking at pictures from stores a few decades ago, it seems that plastic packaging has replaced a lot of other forms of packaging over time. Given the environmental issues from plastics, it seems a good idea to compare different materials.

With pollution and climate change in mind, we should resist the temptation to only look at the most obvious problems. Instead, **we should go through the life of a piece of packaging step by step to see how the different materials measure up to one another.**

RESOURCES AND MANUFACTURING

Let's start at the beginning: every packaging material must be produced from some resources. Both the resource production and the manufacturing process generally require energy and produce waste. While common plastics are made from components of oil, alternatives from renewable, biobased sources exist ("bioplastics"). These can be compostable or biodegradable to some degree, though this is not a given. On the other hand, non-biobased materials can be biodegradable. In either case, **the oil or bioresource needs to be processed to produce the plastic.**

Metal packaging (e.g. aluminium cans) requires mining of ores and the production of the metal. This is a highly energy-intensive process, as it involves the melting and purification of the raw resources. Similarly, **glass** is produced from sands (requiring the right purity of the sand) and a surprising number of additional geological resources. Glas production likewise involves melting which requires a lot of energy.

Paper is produced from plants, which makes it very renewable – though depending on the plant (trees vs. bamboo, for example), the (re)growth time may vary. Paper production is not nearly as energy intensive as glass and metal, but requires a lot of water.

TRANSPORT

Transportation comes up a lot along the value chain. The resources and intermediate products need to be shipped to the next part in the chain, and once the packaging is formed, it too must be shipped – both empty and filled. Here, plastics (both fossil and

biobased) have a leg up on materials like glass and metal (and even paper): plastics packaging is simply lighter than the alternatives.

Why is this important? **Transport uses fuel**, of course, and more of it the heavier the freight. In turn, this **produces CO₂**, among other pollutants. **Lighter packaging means less fuel consumption** and possibly fewer transports overall.

DURABILITY AND DEGRADATION IN THE ENVIRONMENT

Durability is a double-edged sword. Positively, it makes packaging material better at protecting its contents against shock, at reusability and even at recyclability. Negatively, more durable materials will persist if they ever find their way into the environment. No common packaging material will last forever, but many last for a long time.

Typical fossil plastics famously take centuries to degrade in most environments and tend to be ground down to – now omnipresent – microplastics. Compostable and biodegradable materials will degrade in the environment, at least under the right conditions, but this in turn limits their reusability, if they start degrading earlier than intended.

Both **metal and glass** are very durable materials, though glass can of course break on impact, leading to sharp shards. In the environment, both take long to degrade. Metals oxidize over time, though food cans are usually produced from stable materials. Good for durability during use, a problem in the environment. Plus, sharp edges on cans can injure wildlife. Glass can last even longer than plastic or metal, almost indefinitely, if it is not subject to erosion through wind or water.

Pure paper degrades much faster than the other materials, but is usually **not durable enough** to be used for packaging. To mitigate the shortcomings of paper on its own, it is often functionalized with plastics (though alternatives exist) which brings us back to the environmental problems of plastics.

Another durability factor is the **resistance of the material against aggressive foods**. Pickled foods are a prime example, which is why these are often in glasses – glass is highly resistant against the acid in the pickling liquid and also stable enough to carry the weight of the pickled food, making it a prime choice for this kind of product. As metals can be a bit more susceptible to interactions with foods, cans are often lined with plastic to prevent leakage of harmful metal compounds.

FUNCTION

The core function of food packaging is the **protection of food against spoilage**. Apart from any treatment the food itself has undergone, the packaging provides protection against light, oxygen and humidity in the environment, prevents the loss of moisture, and prevents the loss and/or uptake of aromas, depending on the food. Different materials bring different qualities to the table, when it comes to fulfilling this function.

Metals provide a near-perfect barrier against almost anything. This is why canned foods tend to have very long shelf life. Not everything needs to have such a long shelf

life, which is why some typically canned products are also available in (plastic) pouches, then with a somewhat shorter shelf life.

Glass similarly provides an excellent barrier against oxygen, water vapor, and aromas alike. The main issue, at least for some foods, is light, though using colored glass can provide a remedy in these cases.

Plastics have a wide range of barrier functions but **are often far from the near-perfect barrier of metal and glass**. Often transparent, light is not usually kept from the product. Biodegradable options can be included in this, as they come in many different variants. Quite often though, they provide less protection against water vapor compared to some fossil alternatives.

Paper on its own has no barrier worth mentioning and is thus often coated or laminated with other materials. Quite often, these are plastics. On the other hand, **paper can provide good protection against light and mechanical stability**. A prime example of a well-realized combination of the strengths of plastics and paper are yoghurt cups made from thin plastic (for the barrier) and a removable paper sleeve for stability and light protection.

END-OF-LIFE, REUSABILITY AND CIRCULARITY

After packaging has fulfilled its use, it is discarded. Ideally, this should happen in the proper bin and not the environment (otherwise see above). The different materials have different pathways from here on out.

Glass and metal are highly recyclable as they can be molten down and mixed with new material (which, again, costs energy). Both metal and glass can be recycled **practically indefinitely**. During the recycling process, impurities must be removed (especially for glass), which may provide limitations.

For both **paper and plastic, recycling is a bit more limited**. Not every packaging material is suitable for recycling. Some packaging are complex combinations of individual materials which cannot be separated and do not fit into a recycling stream. Plastic and paper packaging not suitable for recycling is usually incinerated. In addition, recycled material tends to retain some impurities. Thus, recycled material is generally not considered to be food safe, severely limiting the application of recycling in the food packaging sector; that is to say: food packaging can be recycled for other uses, but cannot easily become food packaging again. In addition, both paper and plastic tend to degrade during their respective recycling process, which limits the number of cycles that are possible.

Paper recycling is well established but comes with some caveats related to food packaging: **the paper should be clean (i.e. without food residues) and any foreign materials, such as plastic coatings, should be as little as possible and removable during the recycling process**.

Plastics recycling is quite a complex field. In traditional mechanical recycling, the plastic is cleaned, shredded and molten to produce the recyclate, which is often mixed with new ("virgin") material. Alternatives like solvent-based and chemical recycling are

quite new on the market but can remove impurities and produce virgin-grade recyclate. The advantage is clear: the material itself can be used repeatedly, and fewer fossil resources need to be used. The first chemically recycled materials with food contact approval are coming on the market – time will tell, how they fit in. One case where plastics recycling in the food sector is well established is of course the PET bottle. Since they can be separated from other types of packaging easily, and PET is very recyclable, the cycle works well in this case.

Bottles, both from PET and glass, are also often reused. Reuse is a highly circular use of packaging materials but also comes with a few caveats (of course). Obviously, the packaging needs to be cleaned before reuse, with the transport and cleaning infrastructure that comes with it. Packaging that is beyond cleaning, e.g. through black mold, needs to be sorted out and disposed of. And finally, the packaging needs to be resealed after refilling which requires proper layout of the packaging.

This leaves **biodegradable and compostable materials**. The obvious end-of-life option here is the biodegradation either in industrial composition plants or even home composting. The main issue here is that degradation is usually a fair bit slower than preferred, limiting the current application of biodegradable materials. Biodegradability is often touted as a key to circularity and there is certainly something to this point. It bears mentioning that the biodegradation also produces CO₂, where the idea is that it gets bound again in biomass which can then be used to make new materials.

OVERALL COMPARISON

It should be clear that **no single material can be declared the victor**. In fact, material choice involves a balance between all discussed factors and many other factors. The high energy and transport costs associated with metal and glass balance their practically limitless recyclability and their high protective function (which is overkill for many applications). Glass has some additional tricks up its sleeve due to its reusability and chemical inertness, balanced by its brittleness. Paper is very limited on its own and often combined with plastics, but can give some stability and is made from renewable resources, though a lot of water is used in its production and recycling. Plastics are light and highly versatile, but a massive problem if they get into the environment and are limited in their reusability and recyclability. Also, most common plastics require a stream of fossil resources for production. Biobased and biodegradable materials are still in heavy development and may supplement or replace some established materials. They are, however, often somewhat lacking in the functional properties when it comes to the protection of food.

When it comes to the future of food packaging, what can we expect? We will probably see new materials and recycling technologies come into the market and mix it up again – as the wise introduction of plastic packaging did decades ago.