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Analysis on Hazard Factors of the Use of Corrugated Carton in Packaging Low-Temperature Yogurt during Logistics

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Abstract

In this paper, the research object is the use of corrugated carton in packaging low-temperature yogurt, with the focus on hazard factors of external packaging cartons of yogurt in logistics process; on the basis of production, storage and transport links of yoghurt, the factors investigated in this study include relative humidity of storage environment, stock time, storage and stacking, circulation, transportation, handling, loading and unloading procedure; hazard factors and hazard degree encountered in each logistics link are analyzed; finally, the measures to ensure maximum safety and service life of packages of yogurt products are discussed.

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Keywords: yogurt; corrugated carton; logistics; hazard factors

1. Introduction

Corrugated carton is a container made by shaping hollow-structured corrugated cardboard, using paper as raw material, and it is the most widely used container for commodity packaging and transportation currently [1]. Yogurt is a kind of flavor dairy product produced through the fermentation of milk, mare's milk or milks of some other animals by *Bulgaria lactobacillus* and *streptococcus thermophilus*, which requires post processing of low temperature storage and transport [2]. After being filled, yogurt is generally packaged using the corrugated carton for logistics packaging, in order to facilitate the storage, transportation and circulation. However, due to the fact that corrugated carton is made of paper with the corrugated structure as its main supporting structure and special process requirement of yogurt, the mechanical properties such as compressive strength, bursting strength and stacking load of the corrugated carton for packaging yogurt vary with various influence factors of commodity in logistics process.

2. Environmental humidity

Corrugated carton is very sensitive to environmental moisture because it is made of paper. Environmental humidity influences the moisture content of corrugated carton, thus further affecting other relevant properties of corrugated paperboard such as compressive strength. According to regulations of GB/T 6544-2008 (corrugated cardboard) [3] and GB/T 6543-2008 (single corrugated carton and double corrugated carton for transport packaging) [4], the moisture content of corrugated cardboard upon delivery should be no more than 14%, and corrugated cardboard used for manufacturing corrugated carton shall comply with this regulation. According to relevant reports in literatures (Table 1), as corrugated carton moisture content (16.4%) increases from 7.7% to 16.4%, edge compressive strength reduces by 42.6 %, and puncture resistance reduces by 9.09%; compressive strength reduces by 52%. Therefore, only when the moisture content of corrugated carton is controlled at 8-10% can optimal mechanical properties of corrugated carton be achieved.

Table1. Relational tables of The moisture content of corrugated board and mechanical properties

Moisture content (%)	edgewise crush resistance (N·m-1)	puncture strength (kgf/cm)	Compressive strength (KN)
7.7	8190	7.92	4.73
10.3	5950	8.31	3.82
12.8	5500	7.86	2.96
14.6	4820	7.3	2.7
16.4	4700	7.2	2.25

Note: Data from the literature^[5]

In fact, the moisture content of corrugated carton directly depends on the relative humidity of the storage environment. Therefore, Japanese scholars proposed in 1991 that the relation formula of relative environmental humidity and carton compressive strength as presented below ^[6]:

$$P_h/P_0 = -2.68 \times 10^{-4} h^2 + 0.0227h + 0.66 \quad (1)$$

$$P_h/P_0 = -2.68 \times 10^{-4} h^2 + 0.0227h + 0.66 \quad (2)$$

P_h - compressive strength of corrugated carton when relative environmental humidity (RH) is h (KN);

P_0 - compressive strength of corrugated carton when relative environmental humidity (RH) is 65% (KN);

h - Relative environmental humidity (RH)

Studies showed that the influential relationship between relative environmental humidity and physical properties of corrugated cardboard was achieved after the corrugated cardboard was stored under environmental conditions of $23 \pm 1^\circ\text{C}$, RH30%-90% for 8 hours (Table 2). Test results showed that when the relative environmental humidity increased gradually from 30% to 90%, edge compressive strength of the cardboard dropped by 18.97%, and puncture resistance increased by 617.6%; bursting strength decreased by 3.09%; and adhesive strength reduced by 31.39%. It was thus clear that the changes of environmental humidity had great influence on edge compressive strength and adhesive strength, and its influence on some water-soluble adhesives was especially significant (e.g. starch adhesive).

Table 2 The relationship between storage environment relative humidity and mechanical properties for corrugated board

Relative environmental Humidity (%)	edgewise crush resistance (N·m-1)	puncture strength (J)	bursting strength (KPa)	adhesive strength (N·m-1)
30	12218	1.7	1782	1765
50	11360	12.4	2150	1630
70	11231	12.4	1825	1529
90	9900	12.2	1727	1211

Note: Data from the literature^[7]

According to regulations for storage conditions of yogurt in the National Yogurt Standards (GB 2746-1999)^[8], yogurt must be stored at the temperature between 2°C and 6°C. However, there is no regulation available on relative storage humidity, so enterprises need to determine it themselves according to the packaging materials of their products and stacking methods. The survey on storage conditions of different yoghurt manufacturers showed that the majority of these manufacturers maintained relative humidity of the warehouse for yogurt storage at 30 to 70%. According to the test results in Table 2, when the relative humidity of the warehouse for yogurt storage was between 30% and 50%, the edge compressive strength decreased by 7.02%; when the relative humidity was between 50% and 70%, the edge compressive strength dropped by 11.36%; when the relative humidity was between 70% and 90%, the edge compressive strength dropped by 11.86%. Therefore, it was preferable to keep the relative humidity of yogurt warehouse between 30% and 50%. The continuous rise of relative humidity would gradually increase its influence on mechanical properties of external packaging cartons for yogurt.

3. Storage time

As corrugated carton is mainly supported by its corrugated structure, prolonged storage and stacking will produce certain effect on the mechanical properties of the carton. Research showed that (table 3), after the slotting type double corrugated carton (02 type) was stored for three months at the temperature (23 ± 2)°C with relative humidity of (50 ± 5) % (testing environment conditions: temperature 23 °C, relative humidity, 50%), the edge compressive strength of the cardboard dropped by 21.34%; bursting resistance decreased by 29.55%; adhesive strength dropped by 10.65%. After six months of storage, the edge compressive strength dropped by 30.52%; bursting resistance decreased by 36.52%; adhesive strength dropped by 14.39%. The bearing strength of the empty corrugated carton decreased by 20%^[9].

Table 3 The changes of mechanical properties of Corrugated board in the long-term storage in the process

storage time (month)	edgewise crush resistance (N·m-1)	bursting strength (KPa)	adhesive strength (N·m-1)
Standard request	6500	588	980
0	8060	1780	1070
1	7470	1400	1030
2	6960	1310	994
3	6340	1260	956
4	6110	1210	925
5	5780	1160	919
6	5600	1130	916

Note: Data from the literature^[9]

Usually, turnover time of yogurt in factory is very short. Then the yogurt leaves the warehouse after filling and 8 hours of storage in the cold storage. This means that the yogurt is only stored at manufacturer's cold storage for a short time, which has little effect on the external packaging cartons. Next, the yogurt enters the wholesale or the retail links directly. The usual storage time in the wholesale link is around 24h or even shorter. Despite the short storage time, the storage condition of the wholesalers still has to comply with the requirements of corrugated carton storage; otherwise the mechanical

properties of the cartons will be weakened, which is not favorable for turnover and circulation of products. The retail link comprising shopping malls, supermarkets, regular chain and retail stores is usually the link which receives the least attention and is most likely to be neglected, Due to the problems of incomplete supporting hardware, backward technical management and poor professional quality of personnel in most of these outlets, mechanical properties of corrugated carton will seriously declined, causing deformation, leakage of stacked products, secondary pollution of products, etc.

4. Stacking conditions

4.1. Stacking method

The stacking method may produce certain effect on the performance of corrugated cartons. The common stacking methods for products include leveled stacking, well-type stacking, pin rotor stacking, and corrugated-type stacking (see Fig.1).

The influence factor of compressive strength of corrugated carton (load-bearing capacity) is its side walls. Generally speaking, the longer the perimeter of the carton, the higher the compressive strength is; the shorter the perimeter of the carton, the lower the compressive strength is^[10]. Normally, the vertical corrugation is able to bear more load than the horizontal corrugation. Therefore, it is necessary to ensure that it is the vertical corrugation bearing the pressure at the time of stacking. In the whole process of pressure-bearing, two-thirds of the total pressure is carried by the four corners of the carton. The corners of the carton bear the greatest pressure, and the farther away from carton corner, the smaller pressure is. Therefore, the damage to the four corners should be kept as minimum. While stacking, it needs to be ensured that the four carton corners are placed in alignment. In addition, a little deviation of stacking will greatly reduce the strength of the carton. For example, two layer of leveled stacking will reduce carton strength by 18%, while 10mm of deviation will lead to the reduction in carton strength by 25%.

During the practice of yogurt stacking and transportation, corrugated-type stacking is still the common type due to its high stability. Meanwhile, the appropriate distance between cartons guarantees better ventilation between cartons, so that the products can achieve the desired temperature in a relatively shorter period of time. However, this is a method of alternate stacking of the carton edges, which reduces the compressive strength of corrugated carton. Therefore, most manufacturers adopt cartons with relatively high strength, but this will ultimately increases the costs.

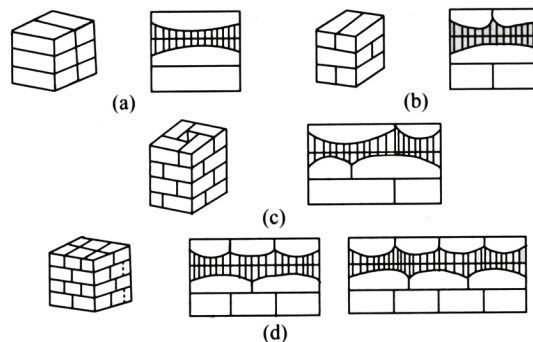


Fig.1. A common stacking way of corrugated box
(a)Flush stacking; (b)Pit stacking; (c)Qin rotary stacking; (d)Tile stacking

1.2. Stacking layer

The number of stacking layer after boxing also has an impact on the mechanical properties of cartons. During the process of stacking, obvious changes occur to strength of cartons at the bottom layer with the increase in number of stacking layers and extension of storage time, i.e. “creep deformation” process. The reason is that relative stable load acts on the cartons for a long time, and the cartons under static load will undergo a continuous bending deflection. As a result of long presence of static load, cartons will be damaged or crushed; the cartons at the bottom layer on a pallet often undergo obvious inflation and some cartons are even crushed^[11]. Under normal conditions, the number of stacking layer varies with the volume of yoghurt. For instance, if eight cups of yogurt are on a pallet, the number of stacking layer should not exceed 14 according to the load-bearing capacity of cartons (height of about 84cm), while the number of stacking layer of yogurt barrels should not exceed 3 (75cm).

1.3. Stacking pallet

The pallet for stacking products also affects the strength indexes of corrugated cartons. Here wooden pallet is taken as an example. Study showed that the optimal spacing between sticks of products storage pallet should be 70mm, because the large spacing of pallet sticks weakens the mechanical strength of corrugated cartons. Meanwhile, every 25mm of hanging-out of cartons beyond the pallet reduce its strength by 32%. According to the survey of yoghurt manufacturers, the currently employed stacking pallets are all wooded flat pallets or plastic pallets and the bottom of the pallet should be of complete leveled structure. Only in this way, the spacing of sticks at the bottom of the pallet will not affect the mechanical performance of cartons.

5. Transportation factors

During the circulation process, packaged yogurt encounters all sorts of factors that cause the decline of the performance of corrugated cartons. For example, during transportation, cartons are under the vibration from all directions, and the repeated impact between the packaged products and cartons leads to the thinning of the carton walls. As a consequence, cartons size becomes inappropriate, and phenomenon such as carton crushing and expansion^[11]. In addition, rigid impact, bumpy road and long transportation journey and of the alternating use of various transportation means during the transportation produce certain effect on cartons, thus greatly weakening the mechanical properties of corrugated cartons. Therefore, in order to guarantee the strength and service life of corrugated cartons, more strict regulations on circulation and transportation conditions for yogurt should be formulated, and technical test and field management strengthened should be strengthened to ensure maximum packaging safety of yogurt products.

6. Handling and loading and unloading factors

In the circulation process of yogurt, handling and loading and unloading links should not be ignored, since they have great influence on the performance of yogurt packaging. Over the past decades, handling and loading and unloading mainly relied on manual loading and unloading as the primary means. Therefore, the strength of corrugated cartons depends largely on the technical methods and working attitude of operating personnel. With the rapid development of unloading equipment and machinery, handling, loading and unloading tools and equipments such as cows, electric forklift, high forklift, conveyor belts, lifter, etc, are adopted. Although these tools greatly improve work efficiency, they may also have certain damaging effect on packaging cartons of yogurts. For example, dropping and falling from high elevation during the handling and loading and unloading process all have serious effect on the

products contained in the cartons. According to the surveys on the manufacturers and distributors of yoghurt, falling from high elevation seldom occurs during its manufacture, but the falling frequency during the distribution process is higher. Moreover, dropping from high elevation occurs frequently, resulting in considerable loss in this link. The dropping position during the handling process produces variable influence too. According to the manufacturers' statistics, most packaged yogurt falls with its bottom touching the ground first, and this phenomenon accounts for about 50%; the remaining 50% includes flip fall, side fall and top face and lateral face fall. In addition, the falling frequency of yogurt products in combined packaging is less than products in independent packaging, with lower falling elevation.

To sum up, the external packaging cartons of yoghurt during the process of logistics are under the influence of various factors discussed above. Each of these factors has different influence degrees. Therefore, manufacturers, logistics enterprises, wholesalers and retailers should pay enough attention to yogurt packaging, and enhance technical management of production, logistics and storage; it is also necessary to promote the awareness of packaging test and inspection and to improve the monitoring and control system for product packaging, so that the quality of product packaging can be improved. Meanwhile, they should constantly strengthen product packaging risk analysis and prevention and remedial measures, which can guarantee the quality of yogurt products to the maximum extent.

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