

Physical Damage of Yogurt. The Role of Secondary Packaging on Stability of Yogurt

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(Received for publication January 25, 1984)

ABSTRACT

Vibratory motions are common to packaged products in the shipping and distribution environment. Using an MTS vibration table, low-fat plain yogurt (packaged in various shipping containers) was vibrated and then evaluated for phase separation (whey-off) during storage. Three types of damage were apparent: (a) slight or definite whey-off, (b) cracked or broken coagulum and (c) completely disrupted coagulum. After 10 d of storage, whey-off was quantitated. Slight and definite whey-off corresponded to 0.2 to 0.6% (wt/wt) and 0.6 to 1.8% (wt/wt), respectively. Most damage was observed in the top layers of vibrated stacks (10 high). Stretch overwrapping the shippers proved most effective in reducing syneresis, with less than 1% of the primary containers evaluated showing phase separation.

Commercial yogurt is packaged and distributed in a variety of ways (Table 1). Evaluation at the retail level shows that physical damage to the product is not uncommon. There are many factors responsible for physical damage (phase separation and broken coagulum) of yogurt, including agitation during transportation and handling (11). Other factors include over-acidification, low solids content, admixture of air, temperature fluctuations, and type and amount of stabilizer. Nielsen (9) and Rasic and Kurmann (11) reported that some stabilizers cause decreased acid production and increased phase separation. Whey separation (syneresis), a physical defect of yogurt, is a common problem and can be controlled. Desirable firmness without syneresis is essential for a quality product (7).

Vibratory motions are encountered by packaged products during shipping and distribution (10). Vibration is common to all modes of transportation, with most products being subjected to some vibration during shipment (1). There are no economically feasible means to completely eliminate the sources of vibratory motions during transportation. Therefore, it is necessary to design prod-

ucts and packages that will withstand vibration without loss in product quality, while at the same time minimizing packaging expense.

While actual evaluation (field tests) of the product-package system through normal distribution channels is a desirable means of testing packaged products, it is usually quite expensive and difficult or impossible to collect data because of the many uncontrollable variables. Therefore, laboratory test methods are used to reduce overall evaluation time and expense.

In a recently published search of factors affecting yogurt storage and packaging, no work on vibration or shock testing was reported (6). Vibration during shipment of other food products has been related to product damage. In the study reported here, a series of trials was designed to observe the effects of vibration at the resonance frequency (maximum amplitude) of yogurt in different commercial distribution packages. Different shippers and overwrap systems were evaluated. Other considerations included in this research were the effects of added stabilizer, shipper performance during incubation, cold storage, and some limited qualitative data on impact shock testing.

MATERIALS AND METHODS

Yogurt processing

Low-fat plain yogurt mix was standardized to 1.5% fat and 12.6% solids non-fat (SNF). The mix was pasteurized at 88°C for 40 min, then cooled to 60°C, and homogenized at 70.3 kg/cm² first stage and 35.2 kg/cm² second stage. This high-heat treatment increases the water-binding capacity in the system and assists in minimizing syneresis. The mix was cooled to 43°C and a mixed-strain yogurt culture was added (2% inoculation). Yogurt mix was filled into 8-oz standard Nestyle waxed paper containers (227-g capacity) to allow for 0.5 in. headspace with plastic lids. The yogurt culture was then incubated at 43°C until the yogurt pH decreased to pH 4.5. The product was then placed in a cold room (5°C) for 2 d. Resonance search and dwell testing was performed on primary (standard Nestyle 8-oz waxed paper board) and secondary (shipper) containers. Each shipper was filled with 12 cups and stacked 10 high in a column arrangement, representative of actual shipping procedures.

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TABLE 1. Characteristics of secondary packaging materials for shipping yogurts.

	Packaging material	Shipper design	Pack size	Primary package
A	Waxed-coated	Cut-out tray	12 - 8/oz pak	Waxed Paper body and closure
B	Single wall corrugated C-flute	Tuckfold box	12 - 6/oz pak	Plastic body and foil closure
C	Paperboard	Cut-out tray packed in milk case 3 high	14 - 6/oz pak	Waxed paper body and closure
D	Waxed laminate insert	Cut-out tray packed in milk case 3 high	9 - 6/oz pak	Plastic body and closure
E	White machine clay-coated chip board	Sleeve tray	12 - 6 oz/pak	Plastic body and foil closure
F	Single wall corrugated E-flute	One-piece folder open top	12 - 6 oz/pak	Waxed paper body and plastic closure
G	Single wall corrugated C-flute	Sleeve with plastic shrink overwrap	12 - 8 oz/pak	Plastic body and closure

Vibration technique

The electro-hydraulic vibration system consists of a control console and a vibration table (Fig. 1). The vibrator maintains a constant input across a broad range of frequencies and the test specimen (yogurt stack) amplifies the input at critical frequencies (8). Such equipment enables one to ascertain resonance, which is the frequency where the acceleration or amplitude is maximal. At this point, any adjustment of frequency will reduce the amplitude or strength of vibration. Gordon and Bains (5) concluded that most unit loads have major resonance frequencies between 7 and 30 Hz.

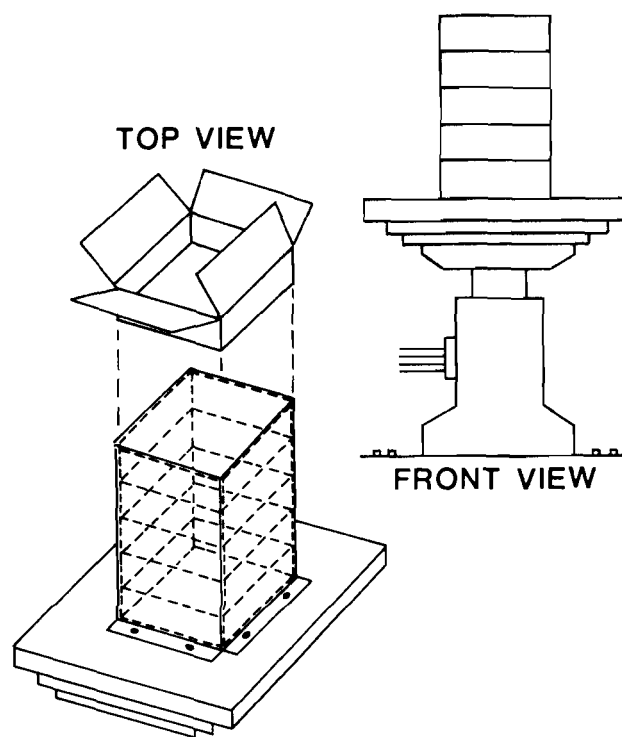
This type of testing procedure employs a frequency sweep over a predetermined range (3 to 40 Hz) to determine resonance points. The frequencies of concern are then held for a period of time (dwell) to determine the likelihood of damage. For evaluation of effects under practical commercial shipping conditions, at least one stacked column of containers is tested (1).

A frequency search (3 to 40 Hz) was made on the stacks composed of the different shipping containers. The types of "shippers" were as follows: I, preformed molded pulp trays individually shrink-wrapped with 1 mil polyethylene (PE); II, wax-coated paperboard trays with no film overwrap; III, corrugated fiberboard sleeves (c-flute) individually shrink-wrapped with 1 mil PE; and IV, corrugated fiberboard sleeves (c-flute) stretch-wrapped over the entire stack.

After establishing resonance, the stacks were vibrated at this frequency (constant acceleration input 0.5 g) for 15 min (dwell time). All stacks were then stored in the cold room at 5°C. After 8 h in the cold room, the yogurt was initially evaluated for product damage. Samples were evaluated on day 2, 5 and 10 after processing. Fresh yogurt is commonly stored for several days following processing before shipment to permit the coagulum to properly set.

Effect of stabilizer

A further study was designed to evaluate the effectiveness of a proprietary blended stabilizer on reducing physical damage, although a good quality yogurt can be made without the use of commercial stabilizers. Fiberboard sleeves, shrink-wrapped (shipper V) and stretch-wrapped (shipper VI) were used as the



MTS VIBRATION TABLE

Figure 1. MTS electrohydraulic vibration table.

test systems. All conditions were similar to those described previously, except for incorporation of the stabilizer. The stabilizer (starch and gelatin) was blended according to manufacturer's directions (1.0% addition).

Incubation and cold storage performance

In a third study, preformed molded pulp trays stretch-wrapped (shipper VII) or left without overwrap (shipper VIII) were evaluated for their performance through incubation and storage. Yogurt containers were filled and placed in trays, and the trays plus primary containers were incubated at 40°C to pH 4.5. All

trays and containers were then placed in cold storage (5°C) for vibration testing.

From previous evaluations, it was noted that more damage occurred in the upper shippers on the vibrated stack. Therefore, dummy products (previously made yogurt) were used in the bottom 5 stacks and new product in the top 5 stacks (layers 6 through 10); only layers 6 through 10 were evaluated for product damage.

Measurement of whey-off

Syneresis or whey-off was indicated qualitatively by: -, no whey-off, ±, very slight, +, slight; and ++, definite. At the termination of storage, the extent of syneresis was quantified by collecting and weighing the free surface whey.

RESULTS AND DISCUSSION

Resonance vibration for waxed paper containers occurred at 22 Hz. Resonant frequency for shippers I through IV was found to be approximately 11 Hz. Eight hours after vibration, 19, 16, 38 and 16% of the primary containers in shippers I through IV, respectively, showed slight or definite whey-off. Ten days after processing, 56, 39, 30 and 13% of the primary containers exhibited whey-off. A comparison between shipper types and phase separation on day 2 and day 10 of processing is shown in Figure 2. Yogurt packed in shippers III and IV showed some reabsorption of surface whey during storage.

At the end of the storage period, the extent of syneresis was quantified. Slight whey-off corresponded to 0.2 to 0.6% (wt/wt) whey and definite whey-off from 0.6 to 1.8% (wt/wt) whey. Control samples which were not vibrated exhibited minimal or no whey-off during 10 d of storage. Latent souring can be associated with increased whey-off, but pH values of the yogurt decreased only 0.1 pH unit during the evaluation period.

At the conclusion of the storage period, definite whey-off (0.6 to 1.8%) was visible in 10 to 20% of the samples in shippers I through III (Fig. 2). Less than 1% of the samples in shipper IV (stretch-wrapped) showed definite whey-off. The yogurt in these shippers also showed the least over-all damage. Twenty-five and 14% of the samples in shippers II and III, respectively, appeared to have broken (cracked) coagulum, whereas in shippers I and IV this type of damage was minimal (<1%). Most damage, for all shippers, occurred in the top layers of the stacks. Stretch-wrapping considerably minimized this type of damage. Statistical analysis using Bonferroni Chi-Square (1,2) analysis revealed that there was a significant difference between shipper types (I through IV) and resulting product damage (Table 2). Individual comparisons using Bonferroni Chi-Square statistics showed shipper IV (stretch-wrapped corrugated fiberboard sleeves) to have less damage ($P < 0.01$) than the other three shippers tested (I, II, III). The most dramatic difference was between shipper IV and II. No significant differences ($P < 0.05$) between other shipper comparisons were noted (II vs. I, II vs. III, III vs. I).

Yogurt is often distributed over wide geographic areas by rail and truck, and because of this, numerous shock

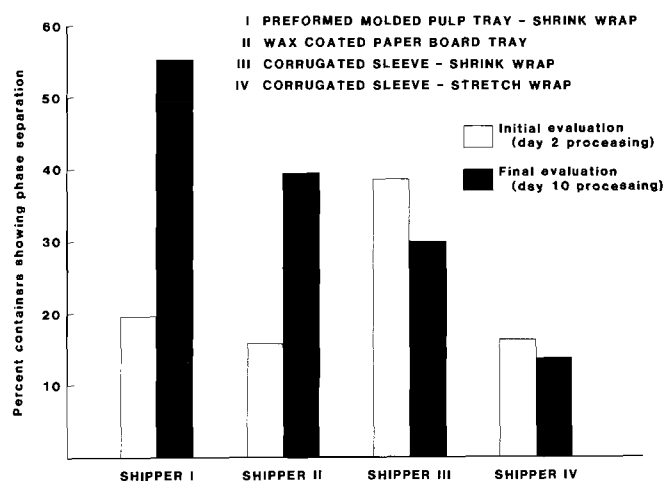


Figure 2. Comparison between shipper types and phase separation.

and vibration inputs can cause product phase separation. Commercial stabilizers are selectively blended to handle these longer and often more severe distribution routes.

No whey-off was observed in any of the containers that had stabilizer added (shippers V, VI; 240 containers total). These data and visual observation of the yogurt coagulum suggest that lower levels of stabilizer (than manufacturer's guidelines) could be used, providing reduced cost without potential increase in product damage.

In a third study, preformed molded pulp trays stretch-wrapped (VII) or no overwrap (VIII) were evaluated for their performance through incubation and storage. After incubation and storage, many of the trays were weak and broke with minimal handling. Some of the primary containers would not sit straight in the trays. The pulp trays which had absorbed moisture were especially weak after cold storage. Vibration testing and product evaluation were made in the same way as for previous experiments. Twelve control samples not vibrated showed none or slight whey-off during the storage period.

Preformed molded pulp trays stretch wrapped after cold storage were difficult to overwrap because of their weakened state. Statistical analyses comparing overwrap vs. no overwrap did not provide strong evidence for either system (Table 2). For each system (VII, VIII), most damage was found in the top shipper vibrated. Because of weakness in the molded trays due to water absorption, the application of a coating, laminating material, sizing agent or other additive is suggested to maintain shipper strength throughout incubation, storage, stretch-wrapping and distribution.

Since product shock is also common in the distribution environment, waxed paper containers with plastic lids (pre-examination showed no whey-off) were examined for physical damage after shock testing. Filled yogurt containers were evaluated for shock damage using an MTS impact shock machine. Samples were dropped from height equivalents ranging from 0.3 to 2.4 m. All samples were carefully caught on the rebound after dropping and evaluated visually for wheying-off and disrupted

coagulum. No disturbances were noted in any of the yogurt samples dropped from equivalent heights ranging from 0.3 to 2.4 m; however, all containers that were dropped and not caught showed disrupted and broken yogurt coagulum. Control samples were not exposed to dynamic shock testing and showed none or slight whey-off after 5 d of storage at 5°C.

CONCLUSIONS

Using vibration testing, the stability of yogurt packed in a variety of secondary packages was tested. Stretch wrapping of shipping containers was also employed as a way to increase stack stability. Yogurt was made with and without addition of commercial stabilizers for the purpose of comparing effect of vibration on nonstabilized and stabilized yogurt.

Vibrated, nonstabilized yogurt had quantifiable levels of whey-off, whereas control samples which were not vibrated exhibited minimal or no whey-off during the storage period. Most damage to the yogurt occurred in the top layers of the stack, regardless of the type of shipper. Stretch wrapping considerably minimized this type of damage.

Yogurt that contained commercial stabilizer and was vibrated showed no whey-off. Hence, product modification can play a very important role in control of damage and should be examined before making expensive package alterations.

Incubation and cold storage of paper-based secondary containers (shippers) can cause changes in the physical structure of the container. This can result in loss of stack stability leading to product loss.

Several factors not examined in this research can also affect product whey-off, such as choice of primary package. In this study, only waxed paperboard containers were used. Yogurt packed in plastic cups of differing designs, of different materials (having different coefficients

TABLE 2. *Packaging terms* (8,10).

STRETCH-WRAPPING. Use of stretchable films such as polyethylene or vinyl to produce a conforming wrap.

PRIMARY PACKAGE. The unit container which is actually in contact with its contents.

SHIPPING CONTAINER. A container which is sufficiently strong by reason of material, design, and construction, to be shipped safely without further packaging either as a primary package or as an outer container for consumer packages (interior containers).

SHRINK PACKAGING. Producing a package by shrinking plastic film over the object or objects to be packaged.

VIBRATION. A mechanical oscillation or motion about a reference point of equilibrium.

VIBRATION TEST. The evaluation of the ability of a filled and closed container to provide protection for its contents against vibration.

RESONANCE. Resonance of a system in forced vibration exists when any change of excitation frequency (called the resonant frequency) causes a decrease in response; therefore, resonance represents a maximum of response, if frequency is varied while input is held constant.

FREQUENCY. The frequency of a periodic function is the reciprocal of the period. The best accepted unit is Hertz (Hz), but many authors use the more descriptive units of cycles per s (cps) or cycles per min (cpm).

RESONANT FREQUENCY. A frequency at which resonance exists.

SECONDARY PACKAGE. The package which contains the primary package at either the consumer or distribution level.

SLEEVE. A tubular form made of various materials, usually open at both ends, made in various shapes which is shipped over or in an item.

MECHANICAL SHOCK. Characterized by sudden changes of excitation that develop significant internal forces in a system. Mechanical shock exists when a force, position, velocity or acceleration is suddenly changed so as to excite transient motions in a system.

NATURAL FREQUENCY. The frequency of free vibration of a system.

FREQUENCY SEARCH. A stack of packages is subjected to vibration from low to high frequencies to find if there are natural frequencies which will cause damage.

DWELL. The packages are subjected to vibration at resonant frequency for an established period to time.

TABLE 2. *Statistical analysis of physical damage^a occurring in yogurt vibrated in selected shippers.*

Shipper comparison	Test statistic	Significance
I - IV	45.72	P<0.001 ^{a,b}
IV vs. I	23.29	P<0.01 ^c
IV vs. II	47.44	P<0.01 ^c
IV vs. III	29.55	P<0.01 ^c
III vs. I	6.534	NS ^d
II vs. III	3.278	NS
II vs. I	0.575	NS
VII - VIII	1.690	NS

^aProduct damage was defined as definite whey-off and disrupted coagulum.

^bComparison of all shippers (I through IV) using Chi-Square distribution ($X^2_{\alpha,3}$).

^cIndividual comparisons using Bonferroni Chi-Square statistics ($X^2 B, \alpha, 6, 1$).

^dNS, comparisons between shippers II vs. I, II vs. III, and III vs. I did not reveal a significant difference at P<0.05.

of friction), and of various sidewall slopes may cause more or less product whey-off. The interrelationship between product stability, primary and secondary packages, and distribution forces needs further examination. This work has shown that secondary packaging does affect product quality.

ACKNOWLEDGMENT

Michigan Agriculture Experiment Station Journal Article No. 10871.

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Micrococcus and/or *Lactobacillus* spp., whereas *Pseudomonas* spp. were dominant on chops packaged in PVC film, and (d) for centralized fabrication and packaging systems for pork loins to be effective, it is recommended that chops be fabricated from fresh pork loins to maximize shelf life.

ACKNOWLEDGMENT

Technical Article No. 19809 from the Texas Agricultural Experiment Station.

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