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Effects of Sinusoidal Vibrations on Quality Indices of Shell Eggs

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In order to assess the effects of the sinusoidal vibrations on indices that characterise the internal quality, five samples of 30 eggs were stressed for 5 h with a constant acceleration of 0·5 g (root mean square value, r.m.s.) at frequency linearly increasing with the time in the 5–20, 20–35, 35–50, 50–65 and 65–80 Hz ranges (one range for each sample). Vibration tests were carried out by means of an electro-dynamical shaker provided by an alveolate surface made of concrete mounted on the vibrating table. After a period of storage, Haugh unit, vitelline membrane strength, yolk index and air cell height were determined. Results showed a significant decrease (23%) of the Haugh unit in the 50–65 Hz range respect the non-vibrated eggs; a low difference in the vitelline membrane strength and the air cell height was observed between the samples vibrated at low and high frequency. In order to determine with more accuracy the frequency with the highest influence on the Haugh unit, the vitelline membrane strength and the air cell height, samples of eggs were also stressed in the 5–10, 10–15, 15–20, 50–55, 55–60 and 60–65 Hz ranges. For the Haugh unit, a very high influence of the vibration was observed in the 50–55 and 60–65 Hz range (44% of maximum decrease with respect to the non-vibrated sample). The vitelline membrane strength in the 50–55 Hz range resulted significantly lower (11%) than in the 15–20 Hz range but the highest difference (13%) was found between the 60–65 and 50–55 Hz range. The highest differences in the air cell (12%) was observed between the 10–15 and 60–65 Hz range.

1. Introduction

The effect of the sinusoidal vibrations on the quality of the agricultural products has been studied by several researchers. Experiments were carried out in order to understand the reasons for in-transit injury of fresh fruits determining their natural frequencies and relate these to the vibration characteristics of the transportation (O'Brien & Claypool, 1963; O'Brien *et al.*, 1965; O'Brien & Guillou, 1969; Chesson & O'Brien, 1971). For this purpose, a laboratory vibrator powered by an electric motor with a table designed to oscillate on soft springs and attached to it a counterweight was set up to provide amplitudes and frequencies covering the range usually measured on the truck. A more modern system was employed by Turczyn *et al.* (1986) to determine the cause of potato shatter bruising; the authors, according to the procedures outlined by the American Society of Testing and Materials (ASTM, 1979), stressed two types of shipping containers of potatoes with sinusoidal vibrations. The system used by the authors included an electrohydraulic shaker, a white-noise function generator, a spectrum shaping filter, an amplifier and a vibration machine control console. With regard to eggs, laboratory tests, simulating transportation strains, were carried out in order to determine the protective ability of several types of egg cartons (Nethercote *et al.,* 1974).

From egg-laying to consumption, several chemical, physical and biological changes occur in the egg (Stadelman & Cotteril, 1995). These changes depend on the conditions of storage: time, temperature and relative humidity are the main factors influencing the components of the egg (Burley & Vadehra, 1989).

The alterations are estimated by quality indices such as the Haugh (1937) unit, vitelline membrane strength (Fromm & Matrone, 1962) and air cell height (EEC, 1991). The Haugh unit is the standard parameter used to evaluate the fluidification of the thick white during storage due to some changes, still not clearly explained, in the gelatinous structure (Robinson & Monsey, 1972;

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Li-Chan & Nakai, 1989) and probably influenced by the increase in albumen pH for the loss of CO_2 through the shell (Burley & Vadehra, 1989; Kato *et al.,* 1975). The Haugh unit is calculated by a formula involving the weight of the egg and the height of the thick albumen immediately surrounding the yolk; fresh eggs present a high Haugh unit and their white parts remain as a turgid mass (Solomon, 1999). The liquefaction of the thick white is also described in a study of the rheological behaviour of albumen (Pitsilis *et al.,* 1984). To prevent liquefaction, Homler and Stadelman (1963), studied the positive effects of oiling the shell of eggs.

The vitelline membrane that surrounds the yolk plays a further role in egg quality (Heath, 1976). Romanoff and Romanoff (1949) reported that, during storage, the increased content of water in the yolk, caused by osmotic migration from the albumen, stretches the vitelline membrane and flattens the yolk. The tendency to flatten the yolk is evaluated by the yolk index, the ratio of yolk height to yolk width. Cardetti *et al.* (1979) indicated that storing cartoned eggs in the horizontal as opposed to the vertical position can involve a better yolk centring but no significant differences in the Haugh unit resulted from the test.

Fromm and Matrone (1962) demonstrated that the vitelline membrane became more elastic and loses its strength in old eggs; to measure vitelline membrane strength, the authors developed a technique that involved a 2 mm capillary tube placed on the vitelline membrane surface and a vacuum produced through the tube; the strength was determined by the time required to burst the membrane. Another method to measure the vitelline membrane provides the use of the texture analyser (Kirunda & McKee, 2000).

The loss of CO_2 is also responsible for the increase in volume of the air cell that is formed by a separation of the two membranes, at the large end of the egg, as the egg contents shrink (Stadelman & Cotteril, 1995).

The air cell is an index used by the European Union legislation for the commercial classification of eggs. Taking into consideration this parameter, eggs are classified according to three categories of freshness (EEC, 1991): A extra $\leqslant$ 4 mm, 4 mm $<$ A $\leqslant$ 6 mm, 6 mm $<$ B $\leqslant$ 9 mm. Other parameters that characterise the internal qualities (*e.g.* Haugh unit) are not provided by the European Union legislation. Stadelman and Cotteril (1995) reported that careful handling and transport are necessary to prevent damage to the air cell and to the general interior egg structure.

Shell eggs can be transported from the packing house to the market over a very long distance. An important Italian packing house reports that 30, 50 and 20% of shell eggs are transported by road over distances of less than 200 km, between 200 and 600 km, between more than 600 and 1200 km, respectively. In other terms, the eggs are frequently submitted to vibrations from 2 to 8 h. So it is reasonable to investigate on the accelerations transmitted to the eggs and the effects on their quality.

The present research assesses the influence of the vibration and relative frequency on the main parameters describing quality of eggs. The purpose of the paper is to furnish indications useful for further researches on the effects of the vibration on eggs considering that the vibration spectra of the eggs can substantially change according to their position in the transport means. To this end, samples of eggs were stressed with sinusoidal vibrations at frequency linearly increasing with the time, in five ranges, of 15 Hz each, from 5 to 80 Hz. After a period of storage, the parameters regarding the internal quality of the eggs (Haugh unit, vitelline membrane strength, yolk index, air cell height) were evaluated. To investigate the frequency with the highest influence on these parameters in depth, other sinusoidal vibration tests were carried out in more narrow frequency ranges (span of 5 Hz) inside the range where a significant decay of quality was observed.

2. Materials and methods

The research was carried out on samples of 30 eggs each. The used eggs were of grade A and weight class 2 (65–70 g) (EEC, 1991) collected during the first week of May from an Italian packing house and from the same poultry farm. The eggs were stored at 18°C, from collection and during the experiments; this temperature is considered representative of the condition at the packing houses, during the transport and at the points of distribution of shell eggs.

Samples were stressed for 5 h with a constant acceleration of $0{\cdot}5\,g$ (r.m.s., $1\,g = 9{\cdot}807\,\mathrm{m\ s^{-2}}$) at frequency linearly increasing with the time ($8{\cdot}33 \times 10^{-4}$ Hz s^{-1}) in the 5–20, 20–35, 35–50, 50–65 and 65–80 Hz ranges (one range for each sample).

For the frequency, acceleration and duration of the tests, it is relevant to consider that the main acceleration peaks characterising road transportation fall into the frequency range chosen in the present experience. The acceleration of $0{\cdot}5\,g$ (r.m.s.), that is higher than that usually transmitted during road transport, was imposed to increase the effects of vibration on the quality parameters of the eggs and to better understand the influence of the frequency; time represents a mean duration of transportation.

Vibration tests were performed by means of an electro-dynamic shaker (Unholtz-Dickie Corporation, S202); an alveolate surface made of concrete (370 mm by 320 mm by 50 mm) was mounted on the vibrating table