J Anim Behav Biometeorol
v.2, n.1, p.20-25 (2014)

ISSN 2318-1265

REVIEW
Artigo de Revisão

Mechanical vibration: what is the importance of this physical quantity in the poultry transport?

Vibrações mecânicas: qual é a importância dessa grandeza física no transporte avícola?

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Received: 20 January 2014 ▪ Accepted: 28 January 2014

Abstract Mechanical vibrations are inherent to any system of transportation. In poultry production, the higher or lower intensity of this agent during the loading of eggs, chicks and chickens, can increase the production losses and decrease the efficiency of the system as a whole. However, despite its importance this factor is still unknown and little considered in the planning of the transport processes involved in the poultry industry. Therefore, the aim of raising the largest amount of data obtained so far to clarify the effects of mechanical vibrations already found in the transport of fertilized eggs, day-old chicks and broilers. A survey of international and national papers, from 1969 to 2014, which showed that the transport of fertilized eggs, the mechanical vibrations may be responsible for the incidence of cracks, in addition to promoting the agitation of internal constituents (yolk and albumen), which could potentially compromise the quality of birth and hatchlings. The transport of day-old chicks and broilers, the vibrations are related to situations of stress, discomfort and depreciation of the welfare of the birds, which still causes drops in the levels of glucose and corticosteroids and thus affect other parameters as the quality of the meat.

Keywords broiler chickens, fertilized eggs, Production losses, stress

Resumo As vibrações mecânicas são inerentes a qualquer sistema de transporte. Na avicultura de corte, a maior ou menor intensidade deste agente durante o carregamento de ovos, pintos e frangos, pode aumentar as perdas produtivas e diminuir a eficiência do sistema como um todo. Todavia, apesar de sua relevância este fator ainda é desconhecido e pouco considerado no planejamento dos processos de transporte envolvidos na indústria avícola. Desta forma, objetivou-se levantar o maior número de dados obtidos até o momento para esclarecer e apontar os efeitos já encontrados das vibrações mecânicas no transporte de ovos fertilizados, pintos de um dia e frangos de corte. Foi realizado um levantamento de trabalhos internacionais e nacionais, de 1969 a 2014, os quais apontaram que no transporte de ovos fertilizados as vibrações mecânicas podem ser responsáveis pela incidência de trincas e rachaduras, além de promover o agitamento dos constituintes internos (gema e albúmen), o que possivelmente pode comprometer o nascimento e a qualidade das aves recém-nascidas. No transporte dos pintos de um dia e dos frangos de corte, as vibrações estão relacionadas com situações de estresse, desconforto e depreciação do bem-estar das aves, o que ainda provoca quedas nos níveis de glicose e corticosteroides e, consequentemente, prejudica outros parâmetros como a qualidade da carne.

Palavras-chave frangos de corte, ovos fertilizados, perdas produtivas, estresse

Introduction

Transportation is an essential component in current system integration of poultry production, it is responsible for loading of fertilized eggs from stock plants to hatcheries day-old chicks from hatcheries to breeding farms and adult chickens and disposal poultry for slaughterhouses. However, this process still receives little attention and many aspects related to it may impose stress on the load, resulting in a higher incidence of productive losses.

Mitchell e Kettlewell (1998) reported that there are multiple factors in transport that can create negative effects

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04

on poultry. Among these factors are: changes in temperature and humidity, airflow and gas, the density of the cargo and road conditions, the design of the truck and driver performance, these related to the greater or lesser intensity of mechanical vibrations (Mitchell e Kettlewell, 1998; Silva e Vieira, 2010; Schwartzkopf-Genswein et al., 2012).

The vibrations are present in the transport of many different types of loads (animal and plant), which has already been proven as the negative effects of the final product. Specifically in poultry production, it is believed that this agent to be a potential cause of damage into fertilized eggs, and stress in birds (one-day-old chicks and broilers). However, as there are few studies focused on the effects of this agent on poultry transport, this review article aimed to raise scientific work between the years 1969 and 2013, to clarify what are the mechanical vibrations, how they act in charge during transport and its relevance in poultry farming.

What are mechanical vibrations?

Any motion that repeats itself after a time interval is called vibration or oscillation (Rao, 2008). According to Sotelo e França (2006) and Rao (2008), vibratory motions manifest in the presence of dynamic nature efforts, that is, the intensity and direction of forces continually change with time, involving the transfer of kinetic and potential energy. In a more simplified form, the vibrations are produced by external events, which act on bodies supported on vibrating surfaces, in such a situation is commonly viewed in cargo transportation (Griffin, 1990; Walber e Tamagna, 2010).

All bodies endowed with mass and elasticity are subject to vibrations (Gomes, 2006). According to Bovenzi (2005), a vibrating body describes an oscillatory periodic motion and with its displacement over a given time interval. In this displacement are involved instant acceleration and frequency. The frequency can be defined as the number of complete cycles of oscillations that occur per unit time, measured in Hertz (Hz). Meanwhile, the instantaneous acceleration (aj (t)) is a vector that specifies the rate of change of speed in an instant of time "t" in a particular direction axis "j" corresponds to the orthogonal axes "x", "y" and "z". The acceleration values are measured in squared meters per second (ms^{-2}) or by gravitational constant (g), which unit is equivalent to 9.81 ms^{-2} (Walber e Tamagna, 2010; NHO 09, 2013).

Second to the ISO 2631 specification (1997), Sotelo and França (2006) and Walber and Tamagna (2010), the direction of the vibratory movements varies continuously regarding to a reference, so that a material point exposed to the effects of this agent can perform shifts in the three orthogonal axes: x (horizontal), y (vertical) and z (transverse). In this coordinate system, there are limits and different exposure level forces, for each axis (x, y, z). The actions of such forces, for example in a transport vehicle, it is described solely by Griffin (1990) and Walber e Tamagna (2010):

- Vertical forces: occur when the vehicle moves in curves, the body moves upwards;
- Longitudinal forces: usually occur when the vehicle is braking and when it passes by a sunken road, the body moves forward and backward;
- Horizontal forces: when the body shell is subjected to average curves at high speeds or abrupt gear changes are performed, the body moves laterally.

According to Rao (2008), for characterization and quantification of various parameters such as vibration displacement and acceleration values are used. However, definitions and units are not always standardized, which creates doubts and the need to adopt a fixed standard of measurement in the study of data, preferably based on existing regulations such as the International Standardization Organization (ISO) 1997 and Occupational Hygiene Norm (OHN) 2013.

How to measure the effects of vibration in field and laboratory

One of the purposes of studying the vibrations is in need to reduce them by appropriate means of transport projects (RAO, 2008). Also, researches are developed to determine the limits of comfort and maximum exposure, which when exceeded they can pose risks to the mechanical or biological systems (Griffin, 1990; ISO, 1997).

From the analysis of its components (acceleration, frequency and direction), it is possible to calculate the level of vibrations, used to estimate the effects on bodies and systems. Rao (2008) illustrated in figure 1, the basic features of a scheme for measuring the vibration levels at which movement of the vibrating body is converted into an electrical signal by a sensor, which may be an accelerometer.

The output signals provide information for data analysis that can be performed as a function of time or frequency of the record. When performed as a function of time, the analysis is done in terms of the mean square root of the instantaneous acceleration values collected by the sensor, as designated by international standards as "Root-mean-square", "single-axis acceleration value (aw)" or RMS signals for the axes x, y and z (ISO, 1997; Griffin, 1990; Bovenzi, 2005; NHO 09, 2013).

According to the specification ISO 2631 (1997), the RMS shows the total value of the associated vibration, which can be measured independently for each axis energy. With RMS values of x, y and z is possible to obtain a measure of

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04

 ISSN 2318-1265

the resulting vibration, the "root sum square", "Total Vibration value (a_v)", or simply RSS, whose unity in the international system is $m.s^{-2}$. RSS is given by the quadratic root of the sum of squares of the RMS value of the accelerations in the x (a_{wx}) RMS y (a_{wy}) and RMS z (a_{wz}) (Randall, 1992; NHO 09, 2013).

The RMS values and RSS are often used by researchers to characterize and track the effects of vibration exposure (Griffin, 1990; Randall, 1992; 1993; Randall et al., 1997; Gebresenbet et al., 2011, Nazareno et al., 2013). According to ISO 2631 (1997), such methods allow quantifying the amount of energy that is transmitted to the vibrating body through accurate sensors, such as accelerometers.

In this same topic, it should be addressed the studies developed with stirrers, ie simulators able to recreate the movements of shipping in a controlled manner, the levels and the frequencies of interest. Some studies in poultry used these simulators, such as the case of research Berardinelli et al. (2003b), Garcia et al. (2008) and Kovácsné and Torma (2012). To Vursavus and Ozguvem (2004) the advantage of these devices under simulated conditions is the ability to study further the damage caused by vibrations and frequencies and evaluate specific bands, which is not possible in real world conditions.

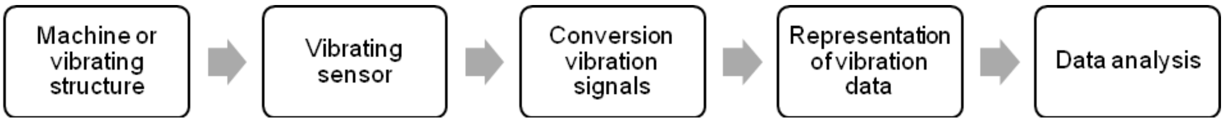

Figure 1 Basic scheme of vibration measurement. Adapted from Rao (2008)

How mechanical vibrations work in cargo transportation

Mechanical vibrations have been addressed in different studies conducted in animal, vegetable and industrial production systems, to determine the effects and bands which are able to compromise the integrity of packaging, fruits, vegetables and eggs as well as the physiological status and meat quality animals (Carlisle et al 1998; Abeyesinghe et al 2001; Berardinelli et al 2003ab; Vursavus e Özgüven 2004; Gomes 2006; Zhou et al 2007; Gebresenbet et al 2011; Nazareno et al 2013).

In a way, the vibratory movements are felt throughout the vehicle. Ranathunga et al (2010) and Walber and Tamagna (2010) explain that the acceleration first pass through the tires and wheels, the later suspension axle and chassis, until they reach the body shell where it is transmitted to the load.

The greater or lesser intensity transmission of mechanical vibrations depends on the following factors: road conditions, determined by the roughness, presence of holes, bend or ripples; truck conditions, ie the number of axes, calibration and maintenance, and also, the performance of the driver while driving, as this is responsible for the variations of speed, overtaking, braking and accelerations (Vursavus e Özgüven 2004; Sotelo e França 2006; Garcia et al 2008; Gebresenbet et al 2011; Nazareno et al 2013).

According to Bovenzi (2005) and Gebresenbet et al (2011), the bodies receive vibrations in different ways, depending on their individual characteristics, the structure which support them and the exposure time. The intensity of these movements also varies across the vehicle, where the acceleration values are significantly different, for example, between the rear and the front position of the body (Zhou et al 2007; Nazareno et al 2013).

According to ISO 2631 (1997) and Brito (2011) standard, the effects of exposure to vibration causes a complex distribution of forces and movements within the body, which are responsible for yielding deformations and dynamic instability situations. In packaging, the vibrations cause failures and breakdowns in the structure aluminum layers (Coltro et al 2002). Fruits and vegetables are also easily affected by this agent, since the majority of kneading, cuts and cracks that compromise their quality, appearance and shelf life (Gomes 2006; Brito 2011; Zhou et al 2007).

In living organisms, the vibrations of transport are related to situations of pain, discomfort and reduce the efficiency of biological systems (Rao 2008). According to Griffin (1990) and Walber and Tamagna (2010), many researchers have been directed to the conditions experienced by humans, with the aim of establishing degrees of comfort without compromising postural stability, and causes symptoms such as muscle fatigue, sickness or amendment respiratory rate. A well-known study is to Randall (1992), which established the reactions of humans exposed to different intensities of vibration (Table 1).

In animal production, the mechanical vibrations have been studied mainly in the pre-slaughter cattle, pigs and poultry transport. It is believed that the transmission of vibratory movements for animals can create uncomfortable conditions, subjecting them to falls and injuries (Randall

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04

 ISSN 2318-1265

1992; Gebresenbet et al 2011), in addition to changing physiological parameters such as glycogen levels which also compromises the quality of meat (Warris et al 1997).

Table 1 Human reactions to different values of RMS (m/s^2)

RMS ($m.s^{-2}$)	Reactions
<0,315	No bother
0,315 -0,63	Little bother
0,5 -1,0	Moderately bother
0,8 – 1,6	Bother
1,25 – 2,5	Great bother
>2,0	Extremely bother

In poultry, the effects of vibrations were quite addressed in the transport of adult chickens for slaughter (Carlisle et al 1998; Randall 1992, Randall et al 1993; Randall et al 1997; Warris et al 1997; Abeyesinghe et al 2001; Garcia et al 2008) and less intense in the transport of commercial eggs (Berardinelli et al 2003ab) and fertilized eggs (Taggart et al 1990; Shannon et al 1994; Torma e Kovácsné 2012; Nazareno et al 2013).

The effects of vibrations on the transport of fertilized eggs

One of the first studies of the effects of mechanical vibration on fertilized eggs was that of Proudfoot (1969), which already thinking in terms of transport, subjected eggs to daily periods of 15 minutes of vibration (3600 $mov.min^{-1}$) before being incubated, together with other factors such as time of storage. In this research, no significant results were obtained, but the author exposed the need to continue studying this agent.

Later there were works of Taggart et al (1990) and Shannon et al (1994) who subjected fertilized eggs to mechanical vibrations during hatching, in order to infer the results for the possible effects of this agent in embryonic development. Taggart et al (1990) evaluated two levels of vertical acceleration, 2,4 $m.s^{-2}$ e 29,4 $m.s^{-2}$, associated to different frequencies of exposure (1, 5 e 10 Hz). The eggs were vibrated for 15 minutes every 3 hours on the 4th, 10th and 14th day of incubation, and in response, the authors obtained a reduction in hatching rate of up to 68% of the eggs of stronger treatment (10 Hz to 29 4 ms^{-2}), when compared to a control group.

Shannon et al (1994) submitted fertilized eggs the exposure of mechanical vibrations with frequencies from 5 to 50 Hz and accelerations from 0.09 to 4.93 ms^{-2} on the vertical axis. The simulations were applied 20 to 24 hours after the start of incubation, for 15 minutes every four hours, every day until the 17th day of incubation. Among the 30 combinations of frequencies and accelerations tested as treatments, there was an overall mortality rate of 31.9%, much higher than the control treatment. In conclusion, Shannon et al (1994) stated that acceleration and frequency of vibration exposure are associated with lower hatching rate.

More recently, Torma and Kovácsné (2012) performed 10 minutes simulations in three different assays. The first and second received vibration test in a range between 10 and 30 Hz, while the third, two levels were applied separately (20, 30 Hz), always at a constant acceleration. The most obvious result found by these authors was also reduction in hatchability, and a higher incidence of embryonic abnormalities.

In their conclusions, Taggart et al (1990), Shannon et al (1994) and Torma and Kovácsné (2012) expose the lethal effect of vibrations on embryonic development, these are applied before or during incubation. According to Nazareno et al (2013), the mechanical vibrations influence in a direct way in the before farm losses. For the same author, the more intense exposure to this agent can increase the incidence of broken and cracked eggs and also contribute to lower levels of hatchability. Taggart et al (1990) add that the eggs subjected to vibrations can have their yolk broken, or the involvement of the primary structures of the fertilized disc, preventing any form of development.

Altuntas and Şekeroğlu (2008) and Nedomová et al (2010) state that within the production chain, eggs are all the time exposed to mechanical impacts that can occur, for example, in collecting, packaging and shipping. Nazareno et al (2013) characterize real conditions of transport of fertilized eggs and found high levels of vibration in both asphalt and land roads. The same authors correlated these results with the percentage of cracked and broken eggs, whose values exceeded 1% in trips which the greatest number of the most intense shock and vibration levels, a note of great validity to the poultry industry were detected.

The effects of vibration on the transport of day-old chicks and broilers

According to Warris et al (1997) for broilers can travel for long periods due to the distance of the farms and slaughterhouses. In this transport, the birds are exposed to a number of stressors, physical or mental, able to compromise the welfare and productive performance (Figure 2) (Mitchell e Kettlewell 1998; Warris et al 1997; Schwartzkopf-Genswein et al 2012).

Randall et al (1993) and Carlisle et al (1998) commented that considering all agents, the mechanical vibration from transport has still received little attention. To them, the vibrations induce the birds to situations of fear and discomfort, whose effects are felt mainly in meat quality.

In real conditions of transport Randall et al (1993) found frequencies up to 10 Hz on the vertical axis and 18 Hz on the lateral axis of transporting chickens trucks for

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04

slaughter, whereas it was proved that vibrations from 2 to 10 Hz cause significant reduction in muscle glycogen of birds (Warris et al 1997). Carlisle et al (1998) also studied the effect of different levels of vibration (2 Hz, 5 Hz, 10 Hz, and a control) to 2 ms^{-2} for plasma glucose levels and cortisol. As a result, the authors have found physiological changes that clearly express the stress of birds due to exposure to this agent.

Physical stressors	Mental stressors
Temperature variations	Social mix
Flow of air and gases	Fear and anxiety
Physical injuries	Food and water fasting
The vehicle vibrations	Deprivation of space

Figure 2 Physical and mental stressors present in poultry transport

Garcia et al (2008) evaluated the change in rectal temperature and weight loss of broilers during exposure to simulated vibrations from transport conditions. In this study, they were adopted as treatments the resulting accelerations (RSS) of 8.7 $m.s^{-2}$ e 22.2 $m.s^{-2}$, both considered extreme aversion. The responses studied in this work, the results were not significant, so that the authors explain the need for more research and the adoption of other parameters.

In addition to using physiological parameters, some work with aversion / choice tests are also used to assess the effects of vibrations on the broiler. In Abeyesinghe et al (2001) research, they combined the vibration exposure to thermal stress. It was found that birds tend to avoid more vibrations, because according to these authors, this factor is noticed immediately and gives fear to animals.

In the case of transport of day-old chicks, the vibrations from transport were even less explored, either in research on physiological parameters or choice tests. Donofre et al (in press) evaluated through simulations the effect of two levels of vibration (9,64 m s^{-2} and 15,19 m s^{-2}) on stress and performance of broiler chicks during the first week of rearing. The vibrations were simulated using a mechanical shaker and vibration levels studied by general acceleration values, or RSS.

The results of Donofre et al (in press) showed that the treatments did not significantly influence ($p < 0.05$) on broiler performance in the first week of life. However, the chicks which underwent a more intense acceleration (15,19 $m.s^{-2}$) obtained a significant increase in respiratory rate (54,33 $mov.min^{1}$), when compared to control and other vibration treatment. In conclusion, these authors stated the vibrations may act as potential stressor also on the transport of young birds.

Final considerations

Through this survey it is possible to verify that the mechanical vibrations involve several segments of the poultry production and, in large part, the effects of this agent are negative and are related to stress and the increase in production losses. However, the transport process is inevitable, there is no way not carry eggs or birds and it is hard to control the quality of roads and trucks. Thus, strategies should be adopted, based on new scientific research that addresses engineering concepts from the development of new vehicles boxes, trays and materials to mitigate vibrations.

References

Abeyesinghe SM, Wathes CM, Nicol CJ, Randall JM (2001) The aversion of broiler chickens to concurrent vibrational and thermal stressors. Applied Animal Behaviour Science 73:199 - 215.

Altuntaş E, Şekeroğlu A (2008) Effect of egg shape index on mechanical properties of chicken eggs. Journal of Food Engineering 85: 606-612.

Berardinelli A, Donati V, Giunchi A, Guarnieri A, Ragni L (2003a) Effects of sinusoidal vibrations on quality indices of shell eggs. Biosystems Engineering 86: 347-353.

Berardinelli A, Donati V, Giunchi A, Guarnieri A, Ragni L (2003b) Effects of transport vibrations on quality indices of shell eggs. Biosystems Engineering 86: 495 – 502.

Brito TTS (2011) Simulador multi-axial. Dissertação, Universidade do Porto.

Bovenzi M (2005) Health effects of mechanical vibration. Giornale Italiano di Medicina del Lavoro ed Ergonomia 27:58-64.

Carlisle AJ, Mitchell MA, Hunter RR, Duggan JA, Randall JM (1998) Physiological responses of broiler chickens to the vibrations experienced during road transportation. British Poultry Science 39:48 - 49.

Coltro L, Dantas ST, Jaime MA, Venâncio DS (2002) Avaliação do efeito do transporte no desempenho de embalagem tipo stand-up pouch para produtos líquidos. Polímeros: Ciência e Tecnologia 12: 69-75.

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04

ISSN 2318-1265

Donofre AC, Silva IJO, Nazareno AC (in press) Vibrações mecânicas: Um agente estressor no transporte de pintos de um dia. Revista Brasileira de Engenharia Agrícola.

Garcia DB, Silva IJO, Barbosa Filho JAD, Vieira FMC, Dias CTS (2008) Evaluation of the effect of vibration in simulated condition of transport of broiler chickens. Proceedings Livestock Environment 8:1-8.

Gebresenbet G, Van de WATER G, Geers R (2011) Vibration levels and frequencies on vehicle and animals during transport. Biosystems Engineering 110:10 – 19.

Griffin MJ (1990) Handbook of human vibration. UK: Academic Press.

International Organization for Standardization. ISO 2631-1 (1997) Mechanical vibration and shock – evaluation of human exposure to whole-body vibration – Part 1: general requirements. International Organization for Standardization 1:27.

Mitchell MA, Kettlewell PJ (1998) Physiological stress and welfare of broiler chickens in transit: solutions not problems! Poultry Science, 77:1803-1814.

Nazareno AC, Silva IJO, Vieira AMC, Vieira FMC, Miranda KOS (2013) Níveis de vibração e choques em diferentes estradas durante o transporte de ovos férteis. Revista Brasileira de Engenharia Agrícola e Ambiental 17: 900–905.

Norma de Higiene Ocupacional. NHO 09 (2013) Avaliação da exposição ocupacional a vibrações de corpo inteiro. Ministério do Trabalho e Emprego 1:64.

Proudfoot FG (1969) Effect of packing orientation, daily positional change and vibration on the hatciiability of chicken eggs stored up to four weeks. Canadian Journal of Animal Science 49:29-35.

Ranathunga CL, Jayaweera HHE, Suraweera SKK, Wattage SC, Ruvinda KKDL, Ariyaratne TR (2010) Vibration Effects in Vehicular Road Transportation. Proceedings of the Technical Sessions 26:9 -16.

Randall JM (1992) Human subjective response to lorry vibration: Implications for farm animal transport. Journal of Agricultural Engineering Research 52:295-307.

Randall JM, Streader WV, Meehan AM (1993) Vibration on poultry transporters. Britsh Poultry Science 34:635 - 642.

Randall JM, Duggan JA, Alami MA, White RP (1997) Frequency weightings for the aversion of broiler chickens to horizontal and vertical vibration. Journal of Agricultural Engineering Research 68:387-397.

Rao SS (2008) Vibrações mecânicas. São Paulo: Pearson Prentice Hall 4:242.

Schwartzkopf-Genswein KS, Faucitano LS, Dadgar P, Shand LA, González TG (2012) Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review. Meat Science 92: 227-243.

Shannon SG, Moran AW, Mason KT (1994) Effect of Vibration Frequency and Amplitude on developing chicken embryos. USAARL Report 95:17.

Silva IJO, Vieira FMC (2010) Ambiência animal e as perdas produtivas no manejo pré-abate: o caso da avicultura de corte brasileira. Archivos de Zootecnia 59:113 -131.

Sotelo JJ, França LNF (2006) Introdução às vibrações mecânicas. São Paulo: Edgar Blucher 1:168.

Taggart LC, Alem NM, Frear HM (1990) Effect of vibration frequency and acceleration magnitude of chicken embryos on viability and development phase. USAARL Report 91:23.

Torma T, Kovácsné KG (2012) Effects of mechanical impacts on hatchability of broiler breeders. MendelNet 19:359-367.

Vursavus K, Ozguvem FZG (2004) Determining the effects of vibration parameters and packaging method on mechanical damage in golden delicious apples. Turkish Journal of Agriculture & Forestry 28:311-320.

Walber M, Tamagna A (2010) Avaliação dos níveis de vibração existentes em passageiros de ônibus rodoviários intermunicipais, análise e modificação projetual. Revista Liberato 11: 1 - 8.

Warriss PD, Brown SN, Knowles TG, Edwards JE, Duggan JA (1997) Potential effect of vibration during transport on glycogen reserves in broiler chickens. The Veterinary Journal 153:215-219.

Zhou R, Su S, Yan L, Li Y (2007) Effect of transport vibration levels on mechanical damage and physiological responses of Huanghua pears (*Pyrus pyrifolia Nakai, cv. Huanghua*). Postharvest Biology and Technology 46:20–28.

DOI http://dx.doi.org/10.14269/2318-1265.v02n01a04