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INVESTIGATION OF MECHANICAL IMPACT ON HATCHABILITY

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1. Introduction

It is more and more common practice to transport hatching eggs to a hatchery on a plastic or setter tray. However, we need to be aware of the scale of damage can be done to the hatching eggs and hatchability. Piezo sensors and data loggers available nowadays make it possible to monitor the mechanical impact, but the relevant literature on the limit is limited.

The author examined the modelled mechanical effect on the eggs with different genetic background, different types of trays and also included a technological step to mitigate the impact of mechanical effect.

2. Objectives

2.1. Examining the suitability of Crazy Fit Massager vibration machine (CFM machine) for modelling transport conditions

In the introductory experiments, the author searched for the answer to the question whether the CFM machine was suitable of modelling transport conditions and the extent to which the mechanical effect induced by the machine would damage the hatchability and which would be the main cause of the hatch failures.

2.2. Testing of different exposure (treatment) times, type of trays and lines

In this series of experiments, the author expanded the investigated parameters by including the male line in addition to the female line, as practical experience shows that the paternal lines react more sensitively to environmental conditions.

In addition to the paper tray, the vibration treatments were also repeated at different duration times on a plastic tray to demonstrate that the packaging material could also affect the damage caused by the mechanical impact.

2.3. Introducing short period of incubation during storage (SPIDES) to alleviate mechanical damage

During the introductory experiments, the author found that if the time elapses between the mechanical treatment and the start of incubation is short, the rate of malformed embryos and early embryonic mortality significantly increased.

At the same time, SPIDES technique can increase the viability of the germinal disc.

This justified including SPIDES treated eggs into this series of experiments.

2.4. Testing the effect of different level of mechanical impact induced at different times in accordance with SPIDES treatments

The author was looking for an answer to the question of how egg transportation before hatching and during incubation (18 days), the mechanical impact on the CFM machine, and the SPIDES used to mitigate the damage affect the hatching result and quality.

The examination of the transport on eggs on the 18th days of incubation is justified because the technology of hatching eggs in the broiler house is showing increasing tendency in Hungary. In this system pre-incubated eggs transported to the farm in order to allow immediate water and feed consumption after hatch and promote the beneficial effect of early food intake for early weight gain and the optimum utilization of genetic potential.

3. MATERIALS AND METHODS

3.1. Examining the suitability of CFM machine for modelling transport conditions

Crazy Fit Massager Vibration Machine (hereinafter referred to as CFM machine) is moved by two-dimensional vibration platforms powered by a 1500 watt motor, enabling the machine to move between 0 and 30 Hz with a maximum vibration amplitude of 12 mm.

In the 1st and 2nd experiments, the author of the thesis treated the experimental eggs at a periodically varying between 10 and 30 Hz, in the 3rd experiment at 20 and 30 Hz, respectively, for 10 minutes

Tinytag © TGP-0605 piezo electronic sensor with data logger was used to check the mechanical impacts under field conditions and mechanical effect on the CFM machine.

Sensors measure acceleration, measurement: m/s^2, equivalent to ~ 9.81 times the gravity acceleration.

From the data of the loggers, the data transformation in each experiment:

$$RMS_j = \left(\frac{\sum_t a(t)_j^2}{N} \right)^{1/2}$$

and

$$RSS = (RMS_x^2 + RMS_y^2 + RMS_z^2)^{1/2}$$

to express mechanical impacts and to ascertain whether the CFM machine properly models the field conditions.

Where RMS calculated in the direction of the x, y and z axes is the square root of the sum of the mean square values of the measured acceleration values. The RSS calculated from this is the square root of the sum of the squares of the acceleration values measured in all three directions.

Also, in each experiment, the author checked and counted the chicks at hatch and determined by egg breakout the proportion of infertile eggs and embryonic mortality at different stages of incubation.

Egg received treatments on paper trays. Eggs originated from female line broiler breeders.

3.2. Testing of different exposure (treatment) times, type of trays and lines

In experiments 4 and 6, eggs were exposed to 10 and 20 Hz constant vibration, while in experiment 5, to periodically varying vibrations between 10 and 20 Hz on the CFM machine. Experiment 4 expanded into examination of male line, while in experiment 5 and 6 eggs received treatments on plastic trays. The exposure time was 5 and 10 minutes in the experiments, respectively.

In this series of experiments, the PhD student used an Onset HOBO Pendant G acceleration sensor, which simultaneously measures gravitational acceleration and deceleration in three dimensions.

3.3. Introducing short period of incubation during storage (SPIDES) to alleviate mechanical damage

In the 7th experiment, the author treated eggs, originated of two different genetic backgrounds, on plastic trays for 5 minutes at the 10 Hz level of the CFM machine.

The data collection was carried out with HOBO® Pendant® G accelerometer. Some of the experimental groups received SPIDES treatment immediately prior to the mechanical impact by providing egg shell temperature of 32 °C for 3 hours. Egg shell temperature was monitored by Tinytag© TK-4023 temperature recording logger.

3.4. Testing the effect of different level of mechanical impact induced at different times in accordance with SPIDES treatments

In the 8th experiment, the author of the thesis exposed the eggs of the vibration groups to 5.5 and 4.5 hours of road transport on setter trays. The first road transport took place before the incubation, while the second road transport took place on the 18th day of incubation.

Eggs originating from two lines with different lines and storage times were included in this study. Eggs stored for less than one week received SPIDES treatment once, eggs stored for longer than one week twice.

In Experiment 9, the mechanical effect was completed also on CFM machine on 10, 20 and 30 Hz treatments in addition to road transport. SPIDES treatment was performed in all cases after the mechanical impact.

During the experiment the effect of turning during storage was also examined.

In all cases, the data was collected with an Onset HOBO® Pendant® G Data acceleration sensor while eggshell temperature was monitored with a Tinytag© TK-4023 temperature recording logger, both during SPIDES treatment and transport of pre-incubated eggs.

4. RESULTS

4.1. Examining the suitability of CFM machine for modelling transport conditions

The experiments confirmed that the CFM machine is capable to expose eggs to a similar mechanical effect that models the transport conditions, and the effects can be repeated, gradually increased by the degree of impact and the statistically reliable difference between the treatment performed.

The hatchability decreased significantly in experiment 3 ($8{,}75^{a}\pm1{,}39$ vs. $76{,}8^{b}\pm2{,}97$ vs. $64{,}89^{c}\pm4{,}27$), which means that the maximum acceleration on a paper tray x 29,4 m/s^2 and 3,74 m/s^2 RSMx already caused a significant decrease in hatchability (calculated from the data of the Tinytag logger attached to the platform).

The decrease in hatchability is mainly attributable to the increase in the level of early embryonic mortality.

This phenomenon is consistent with practical experience. The difference observed in the proportion of early dead embryos is significant in experiment 2 ($9{,}00^{a}\pm2{,}97$ vs. $21{,}68\ ^{b}\pm5{,}29$) and in the results of eggs shaken at 30 Hz in experiment 3 ($0{,}55^{a}\pm0{,}59$ vs. $1{,}85^{bc}\pm0{,}77$). In the direction of the x-axis, this is a maximum of 15,77 and 49 m/s^2 and 3,65 and 45,68 m/s^2 RSMx-induced effect (calculated from the data of the Tinytag logger attached to the platform).

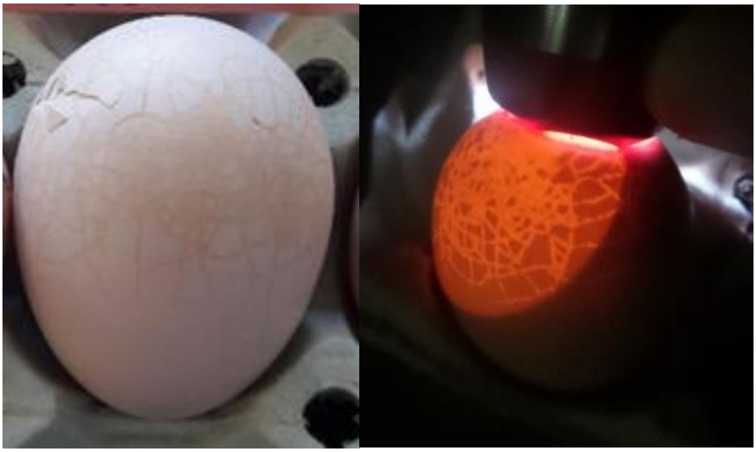
Significant difference was observed between the mid-term (2^{nd} week on incubation) embryonic mortality between the control and 30 Hz group ($0,56^a \pm 0,7$ vs $0,68^c \pm 0,88$) which not in accordance with the observation on the field. But the fact, no any significant difference in late dead mortalities (3^{rd} week of incubation) is similar to large-scale observations.

In Experiment 1. the incidence of malformation and developmental disorders significantly higher ($1,12^a \pm 0,63$ vs. $2,28^b \pm 0,97$) may be related to the short period of time between mechanical treatment and incubation.

In Experiment 2, the proportion of malposition was significantly higher ($2,22^a \pm 1.12$ vs $4.21^b \pm 1.51$).

The "spiderweb" fracture image generated by modelled vibration is the same as that observed during several days of transport.

Picture 1-2: „Spider web" cracks after treatments and at candling



4.2. Testing of different exposure (treatment) times, type of trays and lines

5 minutes vibration even on the "gentlest" packaging material (paper tray) significantly increased the proportion of early embryos ($P < 0.05$) on male line, when less than 24 hours had elapsed between mechanical impact and incubation.

Compared to the treatment on the paper tray, the treatment on the plastic tray significantly ($P < 0.05$) deteriorated the hatchability, mainly by increasing the proportion of early dead embryos.

The duration of the impact is a secondary factor behind the impact force, since, 5 minutes of treatment at 20 Hz and on a plastic tray significantly ($P < 0.05$) increased the proportion of broken eggs and the hatchability of the remaining eggs.

The author achieved this negative effect with a maximum acceleration of 12,26 m/s^2 measured in the x-axis direction and an RSS of 10,02 m/s^2 (plastic tray) calculated from the data of the HOBO® Pendant® G accelerometer.

In this experiment, the lines showed different sensitivity but did not reach a significant level.

4.3. Introducing short period of incubation during storage (SPIDES) to alleviate mechanical damage

This was the first time in the experiments so far that the late dead embryos first showed a significant (Vibration x Line, SPIDES x Line; $P < 0.05$) and near-significant difference (Vibration x Line x SPIDES; $P = 0.058$).

Vibration x SPIDES interaction significantly increased the proportion of midterm mortality (2nd week of incubation) and malformed embryos, which is similar to Experiment 3, where incubation was started within 24 hours after 30 Hz treatment.

This confirms that if not enough time elapses between the mechanical influences and the start of cell division, it can cause abnormal development and increase the occurrence of malformation.

In this experiment the different sensitivity of different lines was observed in relation with the rate of late dead embryos ($P = 0.024$).

Vibration in the female line showed better result than the control. This raises the question of whether a moderate (10 Hz) vibration can have a beneficial effect, mainly in reducing the rate of early dead embryos. As the eggs were not turned during storage, the question arises whether the rotation replacement function can cause this favourable tendency.

The maximum acceleration at 10 Hz up to 14,22 m/s^2 in the direction of x axis and 9,55 m/s^2 RMSx was achieved on the 60 eggs plastic tray. This represented a higher maximum value than the 30 eggs plastic tray at the same maximum acceleration level (10,79 m/s^2), while the

calculated RSMx was the same.
This drew attention to the fact that data transformations may cover part of the relevant information if analyzation of the partial results are ignored.

4.4. Testing the effect of different level of mechanical impact induced at different times in accordance with SPIDES treatments

Different lines benefit from SPIDES treatment differently. In the case of the line that is more difficult to store, ie higher early dead embryos, the SPIDES restore effect of hatchability was higher, especially for multiple treatments.
When the author induced a mechanical effect only by road transport (maximum acceleration in the direction of x axis: 26.5 m/s^2, RSMx: 9.11 m/s^2, RSS: 9.9 m/s^2), there was no statistically verifiable effect to the hatchability. SPIDES, on the other hand, counterbalanced the effect of older egg age.
Based on the results of the experiment, it is not necessary to wait between the mechanical effect and the SPIDES treatment, but at least 24 hours has to be in storage between the SPIDES treatment and launching the incubation cycle.
The greatest damage of the treatment on the CFM machine was the ratio of broken/hairline cracked eggs (CR), which most influenced the results of hatchability and shown strong correlation (P <0.001) and regression with vibration treatment (CR = 0.146 x VIBRATION + 0.124 (R2 = 0.64)).

The calculated RSMx values that caused this effect at 20 and 30 Hz: 10.85; 13,58 m/s^2, while their maximum acceleration values in the x-axis direction: 18,64 and 30,9 m/s^2.

The road transport conditions used in the observation did not negatively affect the hatchability, but the increase in the rate of malformation shows a correlation with the 18-day hatching egg transport.

Therefore, it can be assumed that the embryos may have felt discomfort, since the shell temperature rose to 40-40,6 ^{o}C in the last hour of transport, even with the same transport vehicle and the same air temperature.

Based on calculated Pearson correlation coefficients, the following linear relationships exist:

There is a high correlation between the level of the vibration treatment and the rate of broken eggs ($P < 0.001$), while the negative correlation between the rate of early dead embryos and hatchability of set eggs, hatchability of fertile eggs ($P < 0.001$).

These two latter correlations are significant because there is a moderate, significant positive correlation between vibration treatment and early dead embryos, as well as between early dead embryos and broken eggs, and between early dead embryos and ruptured yolk membrane ($P<0.001$). Consequently, mainly through these parameters, vibration does reduce the hatchability.

5. NEW SCIENTIFIC RESULTS

1. Experiments confirmed that the vibration modelling equipment used in the research effectively simulates transport and egg handling conditions.

2. During the tests, the characteristic “spider web” eggshell fracture image was clearly identified, making it possible to recognize damage caused by vibration in breeding eggs under operating conditions.

3. It was determined that the degree of mechanical impact is more critical than the material of the egg tray or the duration of the impact.

4. During the experiments, the mechanical effect showed close correlation ($r = 0.72$) and regression ($R2 = 0.64$) between broken/hairline cracked eggs and the rate of dead embryos at the early stage of incubation ($r = 0.715$) and mainly through these have had negative impact on the success of hatching.

4. The experiments showed a strong correlation ($r = 0.72$) between the degree of mechanical impact and the proportion of broken and hairline-cracked eggs, as well as embryos that died early in the incubation process, which negatively impacted hatchability.

5. It was found that the RSS mechanical effect of 10,85 m/s2 on the eggs of young flocks with different genetic backgrounds significantly increased the proportion of broken and hairline-cracked eggs, while the RSS mechanical effect of 13.58 m/s2 had a significant negative effect on the hatchability of fertile eggs.

6. Based on the experiments, it can be stated that short period of incubation during storage (SPIDES), applied at the right time, relative to the mechanical effect, can alleviate the negative effect of the mechanical impact if after the mechanical effect the SPIDES treatment is performed and the incubation is not getting started at least for 24 hours. Without giving resting period between SPIDES and launching the incubation the vibration x SPIDES has a significant effect ($P < 0.05$) on the level of midterm dead embryos and the occurrence of malformation.

7. In the course of the investigations, it was also demonstrated that different broiler breeder lines with different genetic backgrounds react significantly ($P < 0.05$) different sensitivity to the mechanical effect and show close interaction with both mechanical and SPIDES treatments.

PRACTICAL APPLICATION

It is important that hatching egg producer companies monitor their own egg handling procedures and the egg delivery conditions to determine the maximum impact the egg suffers during the operation. To determine which technological step can be attributed to it and how much material damage it causes to the company.

Companies engaged in manufacturing automatization for eggs collection, egg handling and eggs transport vehicles may also apply the concept described in the thesis during the design and monitor of equipment and vehicles.

This is based on the symptom complexes observed in the experiments described herein and the established guideline values.

Based on economic analyses, it provides an opportunity to determine how long the economic loss suffered due to broken eggs would cover the targeted technological change or the introduction of a new, gentler technology.

LIST OF PUBLICATION

List of publications in the theme of dissertation

JOURNAL ARTICLES, Peer-Reviewed Papers

In English:

T.Á. Torma and K.G. Kovácsné (2024): Induced and field mechanical effects on the hatchability of broiler breeder hatching eggs, Europ.Poult.Sci., 88. 2024, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2024.397,

In Hungarian:

Torma, Tímea és Kovácsné Gaál, Katalin (2019) A mechanikai hatások befolyásoló szerepe húshibrid tenyésztojások sérülésére és a kelési eredményekre különböző típusú tojástálcákon. Animal Welfare, Etológia és Tartástechnológia, 15 (2). pp. 64-72. ISSN 1786-8440 https://doi.org/10.17205/SZIE.AWETH.2019.2.064

Torma, Tímea Ágnes, Kovácsné, Gaál Katalin (2019): Különböző indukált mechanikai hatások alkalmazhatósága a gyakorlatban húshibrid tenyészállományok tojásainál
Állattenyésztés és Takarmányozás 67: 2 pp. 99-107, 9 p. https://doi.org/10.17205/SZIE.AWETH.2019.2.064 (idézetek száma:1)

Torma, T. Á.; Kovácsné, Gaál K. (2023): A tojáskezelés és tojáskeltetés monitoringja különböző típusú adatrögzítő loggerekkel

Acta Agronomica Óváriensis - Vol. 64. Különszám 1. (2023): 112-118

CONFERENCE ABSTRACTS, International conference, In English:

Torma, T; Kovácsné, G. K. (2017)
Handle with care – controlling loss of hatching eggs and hatchability of broiler breeders due to mechanical impact
European Poultry Science 81 pp. 13-14.

Torma, Tímea; Kovácsné, Gaál Katalin (2013)
Effects of mechanical impacts on hatchability of Broiler breeders
In: Proceedings of Incubation and Fertility Research (IFRG) meeting conference, pp. 12-13., 2 p.

CONFERENCE PROCEEDINGS (published in full)

International conference In English:

Torma, T; Kovácsné, K. G. (2012)
Effects of mechanical impacts on hatchability of broiler breeders
In: Petr, Skarpa (szerk.) MendelNet 2012: Proceedings of International Ph.D. Students Conference
Brno, Csehország: Mendelova univerzita v Brne (2012) pp. 359-367., 9 p. (Idézetek száma: 9)