VARIATION OF VITAMINS AND MINERALS IN FOUR TYPES OF PACKAGING DURING SHELF LIFE OF PASTEURISED EGGS

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Abstract. The aim of the study was to evaluate the changes in the values of minerals and vitamins in pasteurised egg mass in comparison between traditional types of packaging and biodegradable packaging during the storage period with temperature of 0 °C + 6 °C. The containment function of packaging contributes to protecting the environment from the products and the products from the environment. This research analyses the properties and reflects the comparison between four types of packaging: high-density polyethene (HDPE), Polyethylene terephthalate (PET), Doypack (stand-up pouches, DP) and Tetra Rex® Bio-based packaging (TP). The analysis focuses on the impact that different types of packaging have on the shelf-life, vitamins, and minerals during the storage period of the product. The final product was packaged using four previously mentioned packaging technologies - 50 units of samples for each packaging. The changes in quality of samples during storage were represented by measuring Colony-forming units ($CFU \cdot g^{-1}$) using LVS ISO 4833-1:2014 method. Minerals were represented by measuring percentages using LVS EN 14082:2003 method, and vitamins data were compliant with the PN-EN ISO/IEC 17025 standard of laboratory J.S. HAMILTON POLAND Sp. z o.o. During the study, it was concluded that there was no deviation in minerals in each type of packaging. However, there was a significant variation for mineral Calcium (Ca) in HDPE, PET, and DP packaging – from 2.83 to 3.13% on average. On the other hand, the amount of mineral Calcium (Ca) in the TP packaging remained unchanged. As for the other vitamins, changes were notable in PET and DP packaging types – 11% and 12% on average, respectively. The HDPE and TP packaging disparities were less noticeable, no more than 1% on average. The obtained data emphasises the importance of the packaging type, which could provide stable quality of ready to use products for up to thirty five days, preserving valuable components.

Keywords: pasteurised eggs, bio-based packaging, plastic, paper, high-density polyethene.

Introduction

Chicken eggs are considered one of nature's most complete foods because of their high nutritional value. An egg is composed of various nutrients, vitamins, minerals, fatty acids, and protein, making it one of the essential foods in human nutrition. These nutrients are easily absorbed and necessary for the human body's optimal functioning. Furthermore, it is inexpensive and widely available in most countries, allowing low-income people to consume more high-nutrition foods [1].

Eggs contain about 65 percent water, 12 percent protein, 11 percent fat, and 12 percent ash; they also have a low carbohydrate content and only supply 72 calories [2]. It also contains minerals including calcium, iron, phosphorus, copper, and zinc, as well as water- and fat-soluble vitamins like retinol, tocopherol, ascorbic acid, riboflavin, pantothenic acid, and vitamin D. [3]. An egg is considered a food of high biological value because it has all the amino acids required in human nutrition [4].

The word "egg products" refers to eggs that have been broken, filtered, blended, stabilized, pasteurized, cooled, frozen, dried, and/or packaged after being taken from their shells for processing purposes. Whole eggs, yolks, or egg whites that have been treated, pasteurized, and are available in liquid, frozen, or dehydrated form are included in this definition [3]. Eggs are consumed all over the world because they are quite versatile and may be utilized in a variety of culinary recipes. It can be used as a stand-alone dish or as an ingredient to improve texture, flavor, structure, moisture, and nutritional value. Due to technological qualities such as the incorporation of air, gelatinization, and emulsification, which are desirable in meringues, biscuits, bread items, and meat products, eggs are also crucial in the food business [5].

Despite the egg's nutritional importance and functional features, there are various issues with its storage that could affect its quality. The fact that egg is a nutrient-dense product encourages the growth of spoiling and harmful microbes [6]. Another interesting fact is that just 5% of Brazil's entire chicken egg production is allocated for industrial use. The remaining 95% is believed to be for natural consumption, with the eggs not being subjected to quality control before being utilized in any form of preparation, as is necessary in the food industry. Thus, when eggs are packaged or processed, storage conditions such as time and temperature are critical to maintain safety and quality. If there is a quality concern, it will only be obvious to the user at the time of use [7]. As a result, eggs must be treated to extend their shelf life and limit the danger of contamination by foodborne germs. These treatments could be thermal.

To justify packaging, it is critical to understand the impact it can have on a product. To comprehend the impact, we must first comprehend the role of packaging in a specific scenario. The shelf life of a product is the period during which it can be used under certain conditions. The shelf life of the food will be extended if it is packaged properly. Furthermore, one of the most major difficulties that contributes to food-related health issues is the product's shelf life. [8]. After processing, foods must be packaged to minimise any harmful changes in quality. A thorough understanding of food packaging materials' barrier properties is essential for selecting and using them to design packaging systems [6]. Reducing food waste and waste from used packaging can be achieved in two ways: firstly, by increasing the shelf life of products, and secondly, by replacing plastic packaging with an environmentally friendly counterpart [9].

In the egg industry, different types of packaging are used in the production of liquid egg products (Fig. 1). The containment function of packaging contributes to protecting the environment from the products and the products from the environment. This research analyses the properties and reflects on the emerging trends in technology that address innovations in high-density polyethene (HDPE), Polyethylene terephthalate (PET), Tetra Rex® Bio-based packaging (TP) and Doypack (stand-up pouches, DP). The analysis focuses on the impact that different types of packaging have on the shelf-life, vitamins, and minerals during the storage period of the product.

Fig. 1. **Different packaging types for liquid egg products:** a – HDPE plastic packaging; b – PET (polyethylene terephthalate) packaging; c – Tetra Rex® Bio-based packaging; d – Doypack Laminated packaging with EVOH coating

Materials and methods

Fresh shell eggs (Grade A, large size, and uniform age), no older than 5 days after laying were collected from the Latvian farm. Liquid eggs mass was pasteurised using the plate pasteuriser Ovobel AR56SH. The pasteurisation process lasted 69 °C ± 1 °C for 6 minutes. After pasteurisation the liquid product was packed in four kinds of packaging, each packed for 50 units: HDPE bottles 0.5 L with code HDPE21, PET bottles 0,5L with code PET21, TP packaging 0.5 L with code TP21, DP packaging 0.5 L with code DP21. Samples were packed manually in the laboratory.

The liquid eggs mass was stored at temperature 0 °C + 6 °C for thirty-five days in four packaging types. Total bacterial count ($CFU \cdot g^{-1}$) was established according to the standard LVS ISO 4833-1:2014. According to the standard GOST 31469-2012,14 and ISO 1842:1991, pH value was determined using equipment Jenway 3510 Benchtop PH Meter Staffordshire UK.

Vitamin tests were carried out in the laboratory J.S. HAMILTON POLAND Sp. z o.o.: Vitamin A (retinol) method PB-40/HPLC ed. III of 28.02.2009, Vitamin B_2 (riboflavin) method PN-EN 14152:2014-07, Choline B_4 method QMP_504_KI_51_027: 2020-12, Vitamin B_5 (pantothenic acid) 2) method PB-325 ed. I 30.11.2015, Vitamin B_6 (pyridoxine) method PN-EN 14164:2014-08, Vitamin B_9 (folic acid) 3) method PB-327 ed. I 30.11.2015, Vitamin B_{12} (cyanocobalamin) 1) method PB-328 ed. I 30.11.2015, Vitamin D_3 method MSZ EN 12821:2009, Vitamin E (α-tocopherol) method PB-40/HPLC ed. III of 28.02.2009.

Mineral tests were carried out in the Laboratory of Biotechnology LLU: Phosphorus (P), Sodium (Na), Potassium (K), Calcium (CA), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu), method LVS EN 14082:2003.

Data analysis was performed using arithmetical values and standard deviations. Microsoft Excel v16 software was used. The impact of factors and their interaction and the significance effect (p-value) were examined with the Anova Single Factor statistical model.

Results and discussion

The liquid pasteurized egg mass is achieved in the process of punching, filtration and pasteurization of fresh chicken eggs. The structure of packaging and construction play a significant role in determining the shelf life of a food product [10].

HDPE is a high-density polyethylene copolymer with a broad molecular weight distribution and a high molecular weight. The product's design, molecular architecture, and density combine to offer it a unique mix of facile extrusion, high melt strength, and strong physical qualities, making it ideal for manufacturing thin films with good strength and rigidity [11].

PET offers a lot of advantages as a food packaging material: it has a lot of mechanical strength, a lot of chemical resistance, it is very light, can be clear, and has a lot of barrier qualities. PET is also temperature stable over a wide range (-60 °C to 220 °C). PET can thus be used for "boil-in-the-bag" items that are frozen before reheating or in dual-openable containers in particular conditions, as it can withstand higher temperatures than many other polymers. PET is primarily biaxially orientated to improve mechanical strength and gas barrier characteristics [12; 13].

Tetra Rex® Bio-based packaging is a modern, complicated, yet effective method for storing various foods. The primary material in all Tetra pack packages is paperboard. The Tetra pack packaging material structure contains two layers of polyethylene, aluminium, polyethylene, paperboard, and more polyethylene on the outside of the package [14].

Doypack Packaging is a copolymer of ethylene and vinyl alcohol that is used for coating. The addition of ethylene groups reduces the material's water sensitivity (it is no longer soluble in water) and considerably enhances its processability. EVOH possesses exceptional mechanical strength and toughness, as well as good clarity, oil and organic solvent resistance, and gas barrier qualities. It is the most extensively used oxygen barrier plastic in packaging. Because EVOH is costly and vulnerable to moisture, it is rarely used alone [10].

The major goal of the pasteurization procedure and proper packing is to preserve all the important chemical components in the liquid egg mass. The tests carried out showed us the following results for minerals (Figure 2-4).

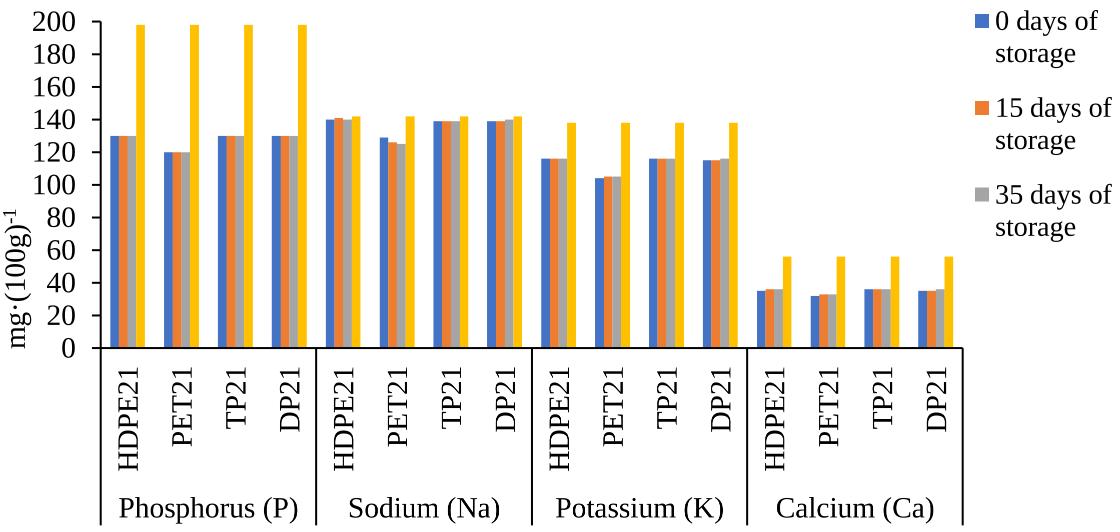

Fig. 2. **Liquid eggs mass, days of storage, content mg/100g, minerals P, Na, K, Ca** in different types of packaging compared with an average measure fromUSDA National Nutrient Database for Standard Reference

The egg is rich in phosphorus, calcium, potassium, and contains moderate amounts of sodium (140 mg per 100 g of whole egg). Copper, iron, magnesium, manganese, selenium, and zinc are among the critical trace elements found in it. The existence of these minerals and micronutrients in the egg is intriguing because a lack of some of them (Zn, Mg, and Se) has been linked to depression, weariness, and the development of pathological disorders [15]. Depending on the hen's diet, the content of some of those trace elements (selenium, iodine) may be greatly enhanced.

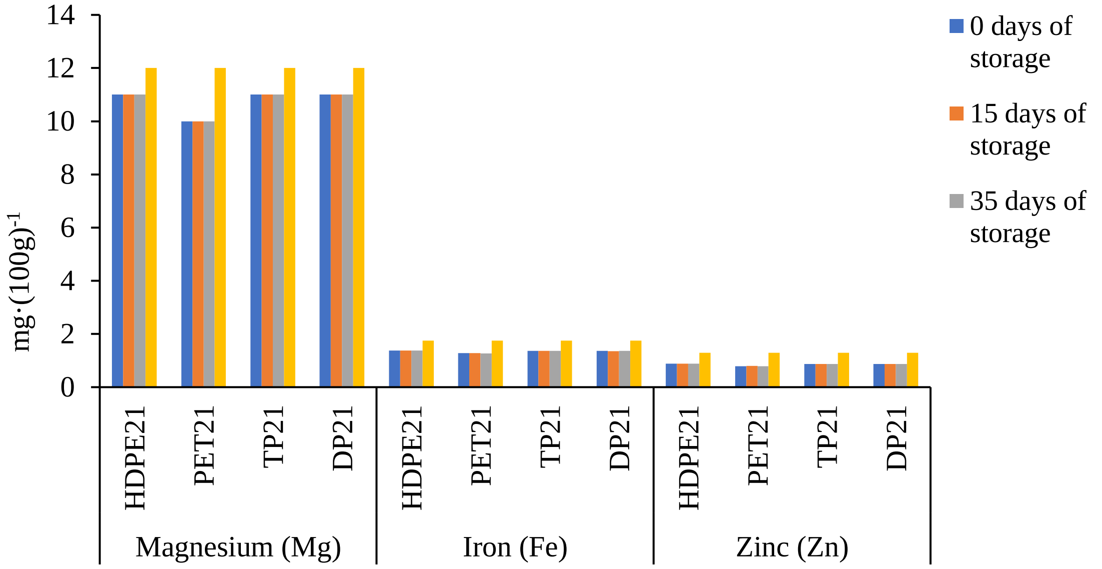

Fig. 3. **Liquid eggs mass, days of storage, content mg·(100g)$^{-1}$, minerals Mg, Fe, Zn in different types of packaging compared with an average measure from USDA National Nutrient Database for Standard Reference**

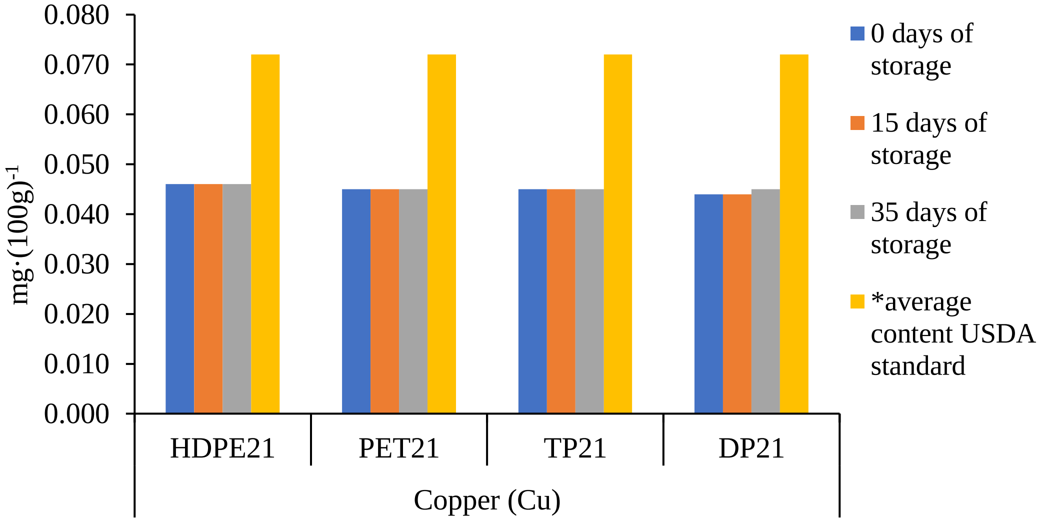

Fig. 4. **Liquid eggs mass, days of storage, content mg·(100g)$^{-1}$, mineral Cu in different types of packaging compared with an average measure fromUSDA National Nutrient Database for Standard Reference**

The results of the test show that minerals P, Na, K, Ca, Mg and Zn packed in packaging PET have a reduction in criteria. As well as all criteria of minerals are significantly lower than the average content provided in bases by USDA National Nutrient Database for Standard Reference and Ciqual homepage for iodine content [16]. Deviations of all elements should be studied in a separate topic on the composition of the feed used in chicken feed.

The liquid eggs mass is a vitamin-rich diet that lacks vitamin C but has all other vitamins (ascorbic acid). The lack of vitamin C in the egg could be due to the fact that birds can meet their vitamin C requirements by synthesising it from scratch from glucose [17]. The ability to produce vitamin C has been lost during the process of evolution in several animal species, flying mammals, humans, and some evolved passerine birds [15].

Vitamins A, D, E, B_2, B_4, B_6, B_9, and B_{12} are abundant in liquid egg mass, whereas vitamins B_2, B_3, and B_5 are abundant in liquid egg white, along with significant levels of vitamins B_1, B_6, B_8, B_9, and B_{12} (Figure 5-7).

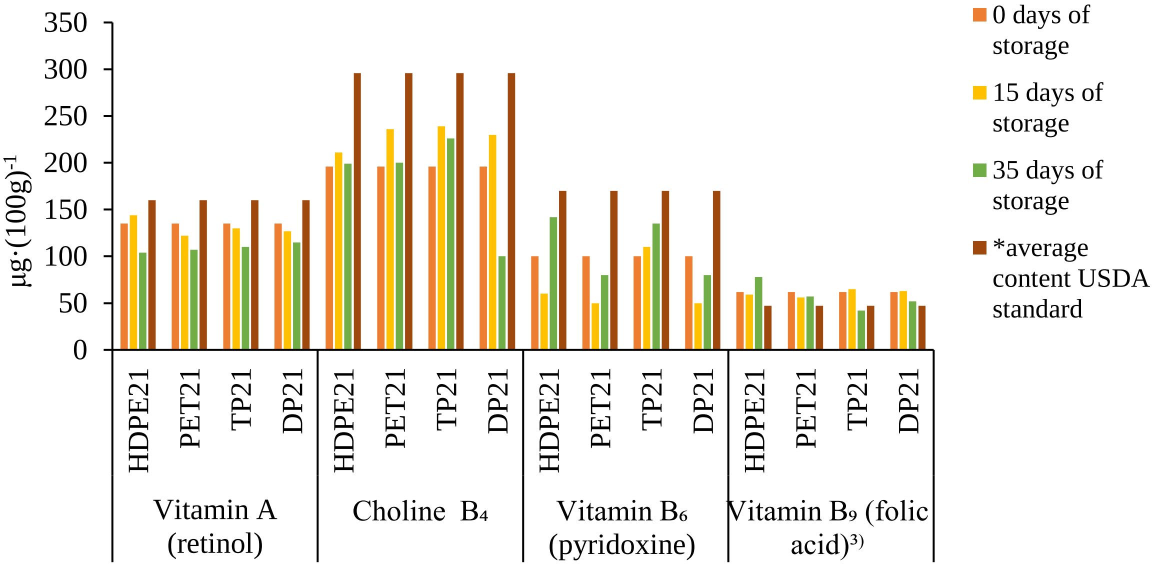

Fig. 5. **Liquid eggs mass, days of storage, content µg·(100g)$^{-1}$, vitamins A, B_4, B_6, B_9 in different types of packaging compared with an average measure from USDA national Nutrient Database for Standard Reference**

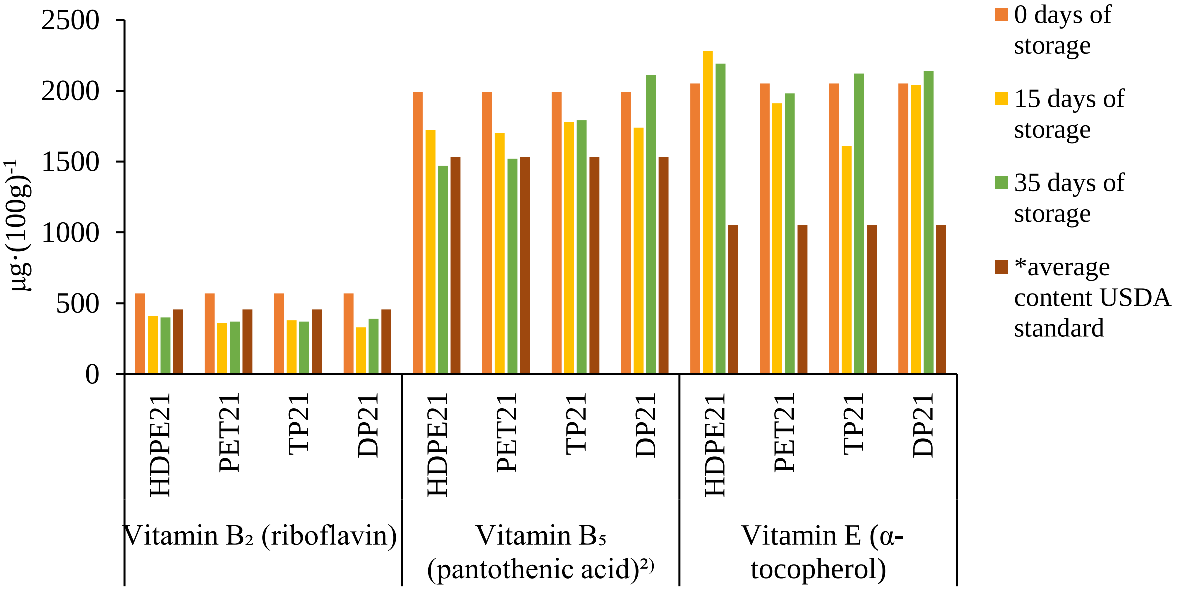

Fig. 6. **Liquid eggs mass, days of storage, content µg·(100g)$^{-1}$, vitamins B_2, B_5, E in different types of packaging compared with an average measure from USDA national Nutrient Database for Standard Reference**

Humans require 10% to 30% of their vitamin requirements to be met by eating two eggs per day or 100mg of liquid egg mass. The amount of liposoluble vitamins (vitamins A, D, E, and K) in egg yolk is strongly dependent on the diet of the hen. Hard-boiled eggs are the second most common source of choline after beef liver [18] and the first source of choline in the American diet [24]. Choline is found in foods in both water-soluble (free choline, phosphocholine, and glycerophosphocholine) and lipidsoluble (phosphatidylcholine and sphingomyelin) forms and plays a crucial role in cellular maintenance and growth at all stages of life. It helps with neurotransmission, brain growth, and bone health [19; 20].

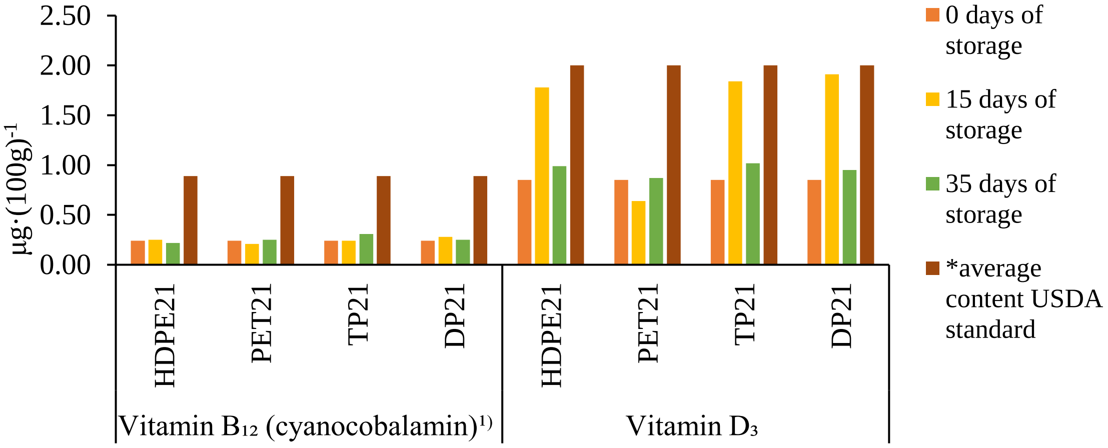

Fig. 7. **Liquid eggs mass, days of storage, content µg·(100g)$^{-1}$, vitamins B_{12} and D in different types of packaging compared with an average measure from USDA national Nutrient Database for Standard Reference**

The results of the test show that vitamins A, B4, B6, B6, B9, and D packed in the four kinds of packaging have a reduction in criteria, the exception vitamin B12 and with an insignificant deviation of vitamin E. As well as all criteria of vitamins are significantly lower than the average content provided in bases by the USDA National Nutrient Database for Standard Reference [16], except vitamins B5, B9 and E. Deviations of all elements should be studied in a separate topic on the composition of the feed used in chicken feed. It is also worth reconsidering the norms in the composition of the feed of vitamins B5, E and D exceeding the average norms according to the USDA National Nutrient Database for Standard Reference.

The criterion which describes product quality on the first day after production is the total bacterial count (CFU·g^{-1}). This criterion is allowed max. $\leq 1\times10^5$ (CFU·g^{-1}). Pasteurized liquid eggs mass issued in practical laboratories showed a different measure of the criterion total bacterial count. Test results are transformed by applying the natural logarithm to the criteria total bacteria count for fourth samples of packaging (Figure 8).

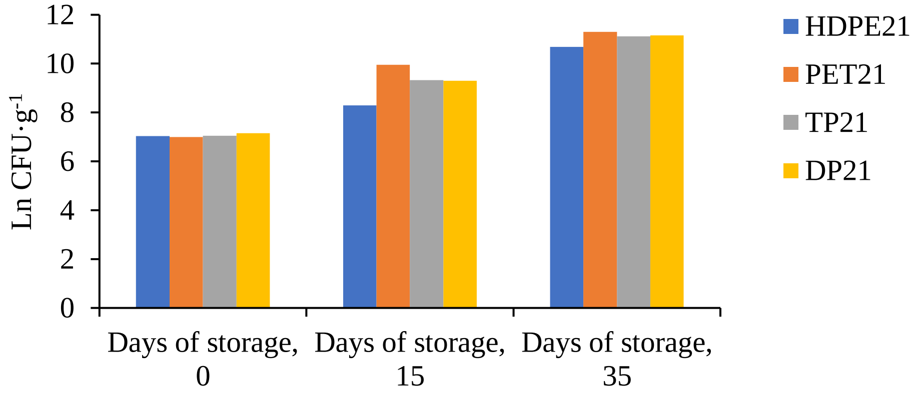

Fig. 8. **Variation during the period of thirty-five days of shelf life, samples HDPE21, PET21, TP21, DP21, criterion Total Bacterial count (Ln CFU·g^{-1})**

Within the shelf-life period of thirty-five days, liquid eggs mass packed in four types of packaging did not exceed the allowable limit max. $\leq 1\times10^5$ (CFU·g^{-1}).

To conclude, fluctuations in the amount of each vitamin and mineral strongly depend on the packaging type used in the manufacturing process. This study also compared the obtained results and USDA average content standard and it is certain that the micro and macro nutrient content is not only dependent on the packaging but on the eggs themselves and feed nutrition [21]. Therefore, manufacturers must consider wisely all the available options for the packaging to find the balance between economic, environmental and quality factors to meet their needs.

Conclusions

1. The samples of liquid egg mass packed in four different kinds of packaging withstood the expiration date of 35 days.
2. The liquid egg mass showed a stable indicator during the test period of 35 days by mineral elements. Deviations for vitamins in the HDPE and TP packaging were no more than 1%. On the other hand, the product packed in the PET and DP packaging shows major deviation in vitamins during the shelf-time – 11% and 12%, respectively.
3. In all types of packages during the storage period of 35 days, significant downward changes were: Vitamin B_2 (riboflavin) – 33%, Vitamin A (retinol) – 19%, Vitamin B_5 (pantothenic acid)[2)] – 13%, Choline B_4 and Vitamin B_9 (folic acid)[3)] – 8%. Certain vitamins had no decline during the 35 day shelf life period but had deviations on day 15 and 35: Vitamin B_6 (pyridoxine) ± 9%, Vitamin B_{12} (cyanocobalamin)[1)] ± 7%, Vitamin D_3 ± 13% and Vitamin E (α-tocopherol) ± 3%.
4. Taking into consideration the results obtained in the study, TP packaging remains superior to the rest of the researched packaging types. TP excels in preserving both minerals and vitamins for the egg mass enclosed in this type of packaging.

Author contributions

Conceptualization, V.K.; methodology, V.K. and S.M.; validation, V.K.; formal analysis, V.K.; writing –original draft preparation, V.K.; writing – review and editing, V.K. and S.M.; visualization, V.K.; project administration, S.M. All authors have read and agreed to the published version of the manuscript.

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