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Meat Technology — Special Issue 64/2

www.meatcon.rs ▪ www.journalmeattechnology.com

UDK: 672.46:664.8
664.91:620.19

ID: 126439945

https://doi.org/10.18485/meattech.2023.64.2.45

Original scientific paper

Porosity and discontinuity of food can protective coatings — simple chemical tests and serious consideration

Zoran Petrović[a], Dragan Milićević[a], Saša Janković[a], Nikola Borjan[a], Danijela Vranić[a] and Dejana Trbović[a]*

[a] *Institute of Meat Hygiene and Technology, Kaćanskog 13, Belgrade, Serbia*

ARTICLE INFO

Keywords:
Food cans
Protective lacquer
Defect
Porosity
Corrosion

ABSTRACT

In order to protect food cans against corrosion, tin coatings and lacquers are employed for internal and external protection. Coating porosity and discontinuity are practical problems in the food canning industry. The prevention of these problems lies in the timely observation and analysis of the scale that can arise in the production of food cans after filling and thermal processing. In this paper, we discuss results of two referenced simple chemical methods (sulphur dioxide and copper sulphate tests) for examining the porosity and discontinuity of food can protective coatings (tin and lacquer layers). In some specific cases, the tests showed precise locations of defects invisible to the eye.

1. Introduction

Satisfactory performance of organic coatings on tinplate depends upon the beneficial interaction of the tinplate surface and the organic formulation when they are joined by the metal roller coater to form lacquer/tinplate interface (*Barilli et al*., 2003). Metal can corrode, leading to a considerable loss of valuable food products and often making products unattractive and unacceptable, especially when food cans are intended for prolonged storage. Another form of corrosion noticed during storage is the under-film corrosion originating at lacquer pores or cracks (*FAO,* 1986). The ability to identify container defects at the start of control in food canneries is the basis for surveillance inspections. Many can defects are associated with the actual manufacturing process, and others are caused by handling of the container in the canning or can manufacturing industry. The main task of the can inspection specialist is to properly identify damaged products and to remove them from the supply system (*AMEDDC&S,* 2023). The organic coating must have satisfactory adhesion and porosity on the substrate (tinplate) and also must follow the movements of the metallic substrate during can manufacturing operations (beading, drawing, plastic deformation, manufacturing, etc).

Tests for continuity are frequently required for coatings of tin on the steel base of tinplate or organic coatings (lacquers) on the tin surface of tinplate. A distinction has to be made between clear gaps in a lacquer coating (wetting failures on the tinplate surface) or breaks made during can-making and the permeability of the film substance itself to molecules and ions (*Britton,* 1975)**.** In this paper, the porosity and discontinuity of protective lacquers was studied at laboratory scale employing copper sulphate solutions and sulphur dioxide test to reveal the loca-

***Corresponding author:** Zoran Petrović, zoran.petrovic@inmes.rs

Paper received April 24th 2023. Paper accepted May 1st 2023.
Published by Institute of Meat Hygiene and Technology — Belgrade, Serbia

tions of unsatisfactory internal end external protection against corrosion changes in food cans.

2. Materials and methods

The cans normally produced and used/or intended for packaging of fruit (pasteurised cherry) and low acid meat product (luncheon meat) were subjected to continuity and porosity tests. Cans were protected using a BADGE- free, organosol lacquer (canned fruit) or epoxyphenolic lacquer a BADGE free (luncheon meat). These types of coatings are commonly used in the food can manufacturing.

2.1. Sulphur dioxide test

A test vessel made of thick tempered glass of volume 30 L, fitted with an airtight closure of glass with a synthetic sealing compound around the rim was used. Solution was prepared using sodium thiosulphate ($Na_2S_2O_3$) crystal (Sigma Aldrich), 10 g/L and sulphuric acid (H_2SO_4; Merck) 0.1 N (4.9 g concentrated acid in 1 L). A volume of $Na_2S_2O_3$ solution equal to 1/20 of the capacity of the test vessel was introduced into the bottom of the vessel. A volume of H_2SO_4 equal to ¼ of the volume of $Na_2S_2O_3$ solution was then added to the vessel. After 5 minutes, test cans were hung on lines, fed through a little hole in the can wall previously drilled with a spike, then introduced in test container and lowered carefully into position in the test vessel so that no part of the can surface was more than 300 mm or less than 100 mm from the surface of the solution. Each can was more than 20 mm distant from other cans and from the walls of the test vessel. The vessel was closed and the cans left undisturbed for 24 h (Figure 1). Areas of exposed steel appear as dark reaction spots and the coating was assessed according to the number and distribution of these spots (Figure 2).

2.2. Copper sulphate test

Immersion test solution was prepared by dissolving 200g Copper(II)sulphate pentahydrate crystals ($CuSO_4 \cdot 5H_2O$; Merck) + 15 g sodium chloride (NaCl; Merck) in a normal vessel (1000 mL) by adding 2 ml hydrochloric acid (36%) (HCl; Merck). Test cans were introduced into a volume of solution enough for complete immersion during 30 minutes (plastic container). After this period, the cans were removed from solution with tweezers, gently rinsed with water and observed for deposited reddish spots (Figures 5 and 6).

3. Results and discussion

Typical surface spots visible after the chemical treatments described in Sections 2.1 and 2.2 are presented in Figures 1 to 6. Figures 1–4 are in relation to results of sulphur dioxide test and Figures 5–6 are in relation to copper sulphate test.

By observing the distribution of spots (Figures 2 and 3), it was established that coating damage occurs usually at the stamped end profile rings (Figure 2) or embossed beadings (can wall reinforcements) inside the can. Visual inspection of the defects present showed characteristic increases in the length of the lacquer cracks (Figure 3) inside the can. It seems that the elasto-plastic wave propagation of cracks (Figure 4) is in relation to internal stresses in the coating (*Fitzsimons & Parry,* 2011) where the surface shrinks faster than the layer of the coating film during can body fabrication and also due to the nature and acidity of content (pasteurized cherry).

The characteristics of the content can be of influence, although some types of fruit are less acidic than cherries, but also a greater corrosive potential that can undermine the lacquer and tin coating. The corrosion potential of the fruit being preserved is related to the profile of the organic fruit acids present, not the measured acidity itself (*FAO,* 1988).

On the one hand, the problem can be viewed from the point of view of the general flexibility of the coating applied, which is visible only after thermal processing and storage of the cherry cans. In this case — cracking of the protective coating is considered as a phenomenon and not a classic loss of adhesiveness (Figure 3). On the other hand, numerous factors influence the surface of the tinplate coatings, so the wetting of the organic coatings during application can be considered, as can possible contamination of the surface of the tinplate sheets before applying the coating, an unsuitably large amount of lacquer applied, high content of tin oxide on the surface of the tinplate if it has been stored for a long time, especially in warm and humid conditions, and a small amount and/or uneven distribution of the chrome passivation layer on the surface of the tinplate (*Benitez et al.,* 2006*; ITRA,* 2000). Furthermore, the topography of the surface of the tinplate, which has a high roughness, affects the distribution of the passivation layer of chrome, which is desirable for the stability of the organic coating that is applied, or could mean low deposit of tin in certain zones of the sheet, etc. (*Berk,* 2009). Can examinations using the faster copper sulphate test method by total immersion of cans (Figures 5 and 6) for 30 minutes produced visible indica-

Figure 1.

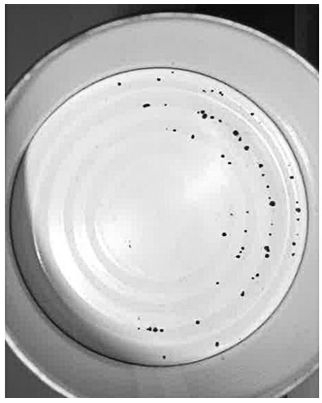

Figure 2.

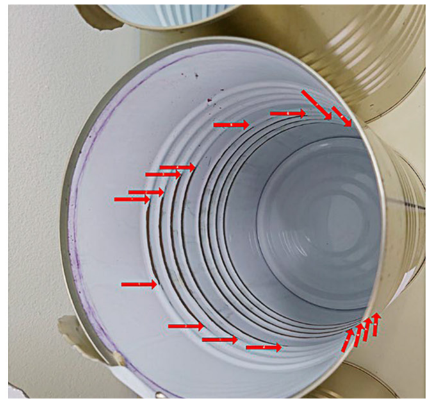

Figure 3.

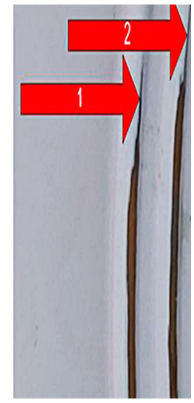

Figure 4.

Figure 5.

Figure 6.

tions (deposits of copper) where lacquer porosity or discontinuity were present (internal protection of the can body welded joint and external surface of double seam around the can bottom). These spots would be the critical places where corrosive changes in subsequent food can production steps could occur. Primarily these problems can include: impurities in the processing water, longer cooling period after thermal processing, inadequate water drainage from cans, slow drying and poor storage and transportation conditions (*CAC,*1993). Electrochemical measurements (impedance measurements, polarization curves, potential measurement) can be carried out on cans, on a model solution or on the food product itself (*Montanari et al.,* 1996). These quantifiable measurements are comparable numerically in contrast to the chemical methods used in this study.

4. Conclusion

The sulphur dioxide test is very effective in revealing areas in cans where lacquer protection has been diminished by can making operations (stamping, beading, flexing, seaming), but the test is too slow for routine control measures. This method reveals the exposed steel base of tinplate used in can making process.

For lacquered tinplate intended to be used in food can fabrication for low acid products, the copper sulphate test gave a fast and effective indication all of the gaps and discontinuities in the protective lacquer film applied during can manufacture. Although this type of test does not give a numerical result (unlike instrumental electro-chemical measurements), other than an estimation of the number of discontinuities, it has the advantage that the position of the discontinuities is made clear.

Disclosure statement: No potential conflict of interest was reported by the authors.

Funding: This work was supported by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia, according to the provisions of the Contract on research financing 2023. No 451-03-47/2023-01/200050 dated from 03.02.2023.

Acknowledgements: We dedicate this work to our long-time colleague retired metal packaging specialist — technician Miroslav Mažibrada.

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