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Study of riboflavin and vitamin A degradation as a function of temperature and light exposure in milk

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Abstract

The effect of light exposure (1100 and 3000 lux) on riboflavin and vitamin A changes in whole pasteurized milk stored at 5 and 10ºC in containers, made of (a) opaque high density polyethylene (HDPE), (b) polyethylene terephthalate (PET), and (c) coated paperboard carton (CPC), were monitored for a period of 7 days. Results showed satisfactory protection of milk packaged in HDPE and CPC bottles. PET bottles provided less protection compared to HDPE and CPC indicating the damaging effect of light on vitamin content of milk. Vitamin A losses, recorded after 7 days of storage at 5ºC under exposure of 3000 lux, were, respectively, 19, 10, and 35% in samples packaged in CPC, HDPE and PET bottles. Respective losses for riboflavin were 16, 14 and 34%. Riboflavin and vitamin A photodegradation were found to follow 1st and 0 order kinetics, respectively. Light and temperature sensitivity of both degradation reactions were also estimated.

Introduction

The main factors affecting the keeping quality of pasteurized milk are raw milk quality, severity of heat treatment, post pasteurization contamination and storage temperature. Packaging is also a factor of utmost importance, effectively protecting the product from microbial recontamination, light and oxygen (Zygoura et al., 2004).

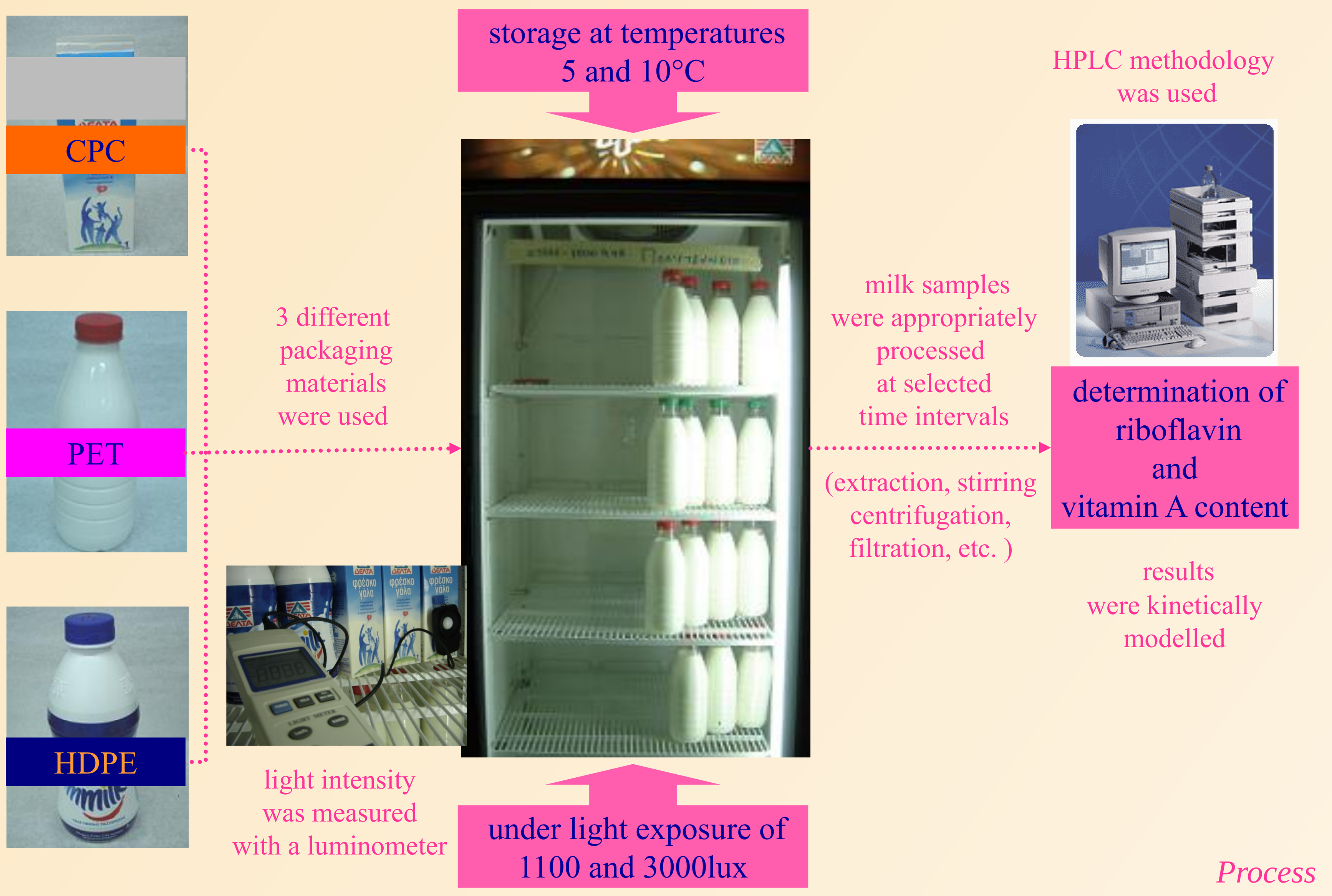
Apart from traditional glass bottles and coated paperboard cartons, all-plastic containers (e.g. high density polyethylene), have been used in pasteurized milk packaging. Problems with all-plastic containers include transmission of light and permeability to oxygen (Rysstad et al., 1998). More recently, polyethylene terephthalate have been used for fresh milk packaging due to consumer preference for transparent packaging material.

Light exposure, especially at wavelengths below 500 nm, causes destruction of light-sensitive vitamins (riboflavin, vitamins A and C) and induces chemical reactions that affect milk proteins and lipids, leading to unpleasant flavors (Cladman et al., 1998). Storage under fluorescent light in supermarket cabinets to attract consumer may affect milk nutritional value and quality.

The objective of this work was to evaluate the light and temperature stability of riboflavin and vitamin A of pasteurized milk under actual conditions of storage in three commercial packages.

Materials and Methods

Pasteurized whole milk (3.5% fat) was studied in three different packages: coated paperboard carton (CPC) and plastic bottles of opaque high density polyethylene (HDPE) and polyethylene terephthalate (PET). Milk packages were stored at temperatures 5 and 10ºC for up to 7 days under light from a 55W cool white fluorescent lamp in a commercial display cabinet. The fluorescent lamp produced 1100±30 and 3000±50 lux on the side surface of the containers, measured with a luminometer (Lutron LX-1102, EU) (*Process*). Riboflavin and vitamin A degradation with time was measured by High Performance Liquid Chromatography methodology (HPLC) (Ashoor et al., 1983; Renken and Warthesen, 1993) and kinetically modelled.



Process

Results and Discussion

Riboflavin and vitamin A content of milk

In figures 1(a) and 1(b), the riboflavin and vitamin A content of milk packaged in CPC, HDPE and PET bottles and stored at temperature 5ºC under light exposure of 3000 lux are representatively shown . According to results, PET bottles led to significantly more losses of riboflavin and vitamin A in milk compared to CPC and HDPE bottles. The riboflavin content losses were higher than the respective vitamin A losses in all experimental conditions.

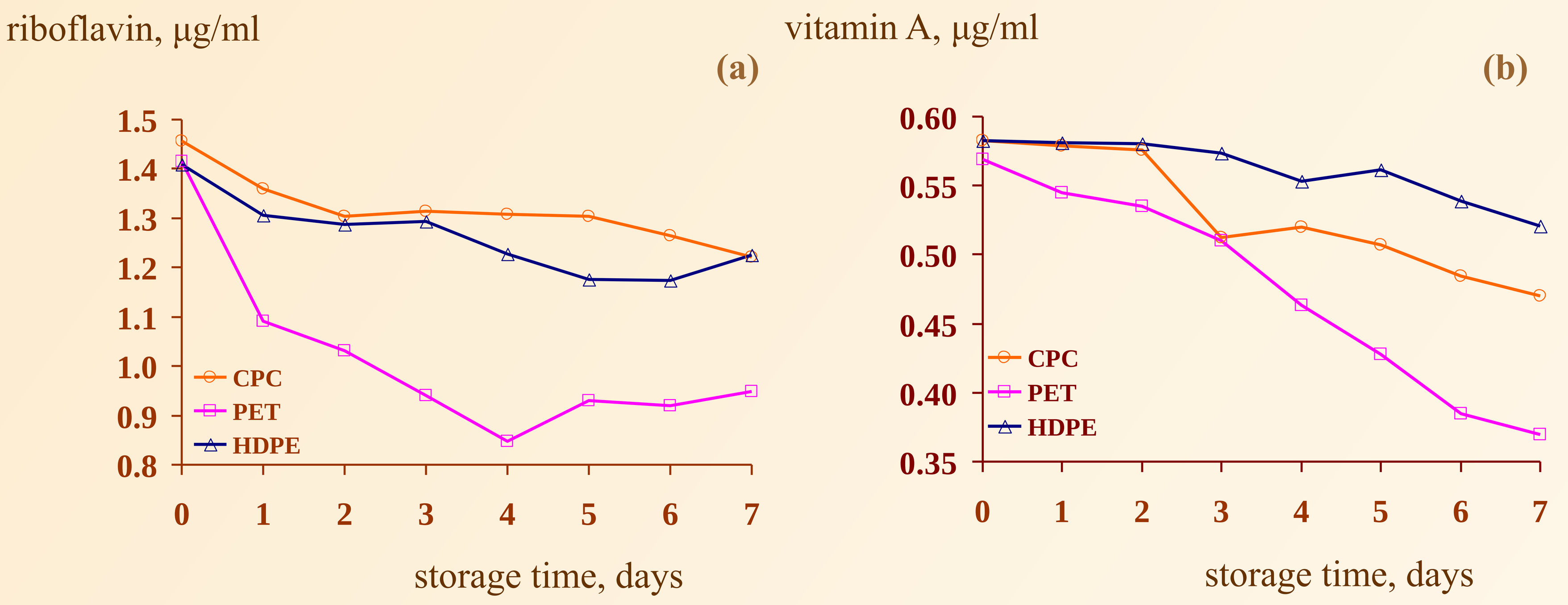


Fig. 1. Retention of (a) riboflavin and (b) vitamin A in whole pasteurized milk packaged in CPC, HDPE and PET containers during storage at temperature 5ºC under light exposure of 3000 lux.

Kinetic modelling of riboflavin and vitamin A photo-degradation of milk

Riboflavin photo-degradation was better described by an apparent 1st order degradation mechanism,

$$C_{rib} = C_{rib_o} * [\exp(-k_{rib} * t)] \quad (1)$$

where C_{rib}, C_{rib0}, riboflavin concentration, μg/ml, at time t and zero, and k_{rib}, reaction rate constant, d^{-1}.

Vitamin A degradation was described by apparent 0 order kinetics,

$$C_{vitA} = C_{vitA_o} - (k_{vitA} * t) \quad (2)$$

where C_{vitA}, C_{vitA0}, vitamin A concentration, μg/ml, at time t and zero, and k_{vitA}, reaction rate constant, d^{-1} (Renken and Warthesen, 1993).

Riboflavin and vitamin A degradation rates (k_{rib}, k_{vitA}) calculated according to Equations 1 and 2 were demonstrated in Table 1.

Table 1. Riboflavin and vitamin A degradation rates (k_{rib}, k_{vitA}) for milk packaged in CPC, HDPE and PET bottles.

packaging material	storage temperature (°C)/ light exposure (lux) conditions		
	10/1100	10/3000	5/3000
	riboflavin degradation rate constants (k_{rib}, d^{-1})		
CPC	0.0018	0.0018	0.0008
HDPE	0.0018	0.0018	0.0009
PET	0.0053	0.0039	0.0020
	storage temperature (°C)/ light exposure (lux) conditions		
	10/1100	10/3000	5/3000
	vitamin A degradation rate constants (k_{vitA}, d^{-1})		
	0.0006	0.0009	0.0008
	0.0004	0.0006	0.0009
	0.0011	0.0011	0.0020

Temperature and light sensitivity of riboflavin and vitamin A content of milk

An increase of light intensity from 1100 to 3000lux caused a 20% increase of riboflavin degradation rate for PET milk. Light intensity increase had no effect on riboflavin degradation rate of milk packaged in CPC and HDPE. The same was observed for vitamin A degradation rates (Table 1).

Compared to light intensity effect, the storage temperature effect was more pronounced for all milk packages studied. Samples in PET exhibited a loss of 35%, followed by CPC (19%) and HDPE (10%), when stored at 5ºC for 7 days under light exposure of 3000lux. The corresponding values for PET, CPC and HDPE samples at 10ºC were 38, 24 and 19%, respectively.

Combined effect of packaging material, temperature and light exposure on riboflavin and vitamin A content of milk

In Figures 2(a, b, c, d), riboflavin and vitamin A losses (%) in whole pasteurized milk packaged in CPC, HDPE and PET containers during 6 days of storage at temperatures 5 and 10ºC under light exposure of 1100 and 3000 lux were representatively shown.

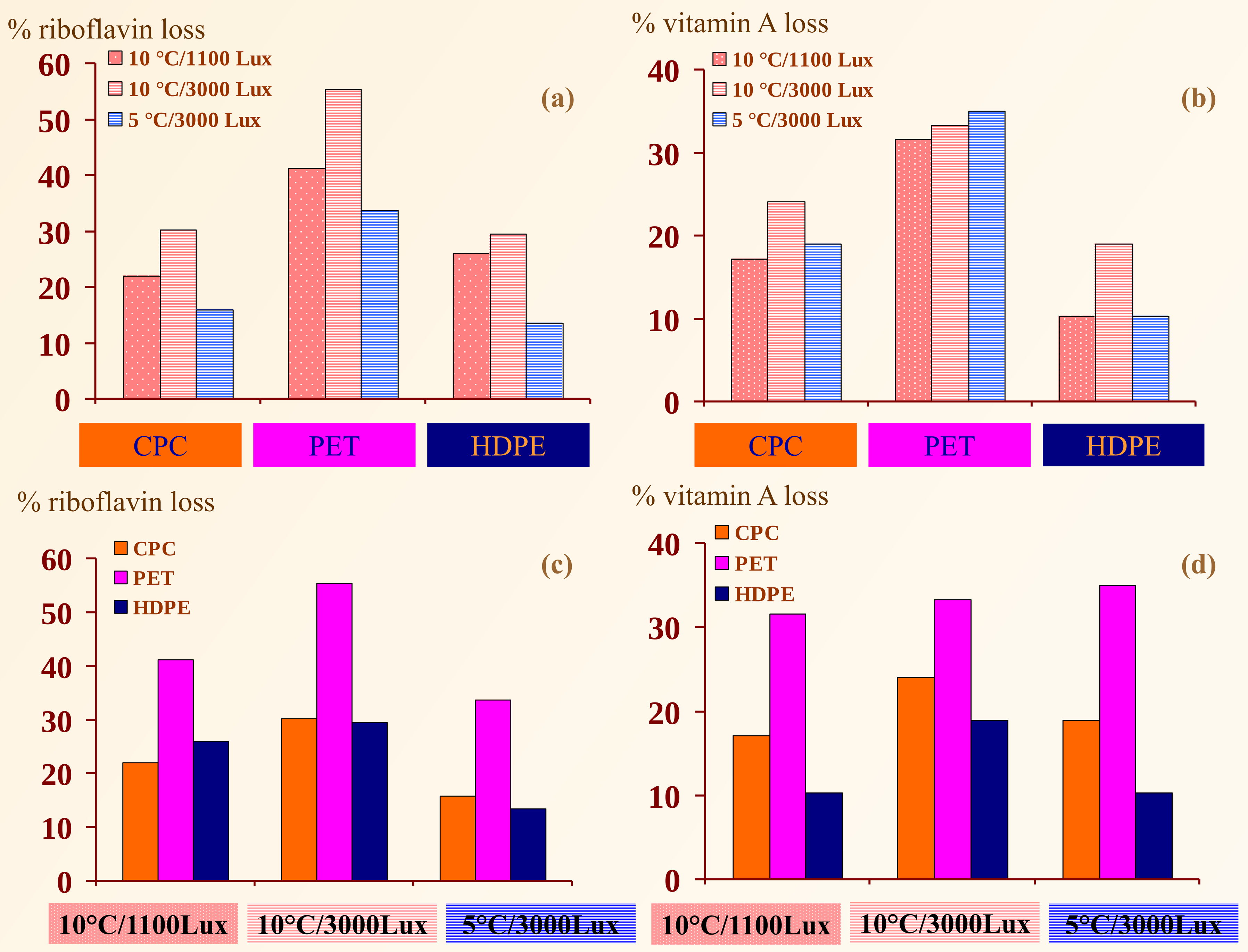


Fig. 2. Riboflavin and vitamin A losses (%) in whole pasteurized milk packaged in CPC, HDPE and PET containers during 6 days' storage at temperatures 5 and 10ºC under light exposure of 1100 and 3000 lux. (a, b) **Effect of packaging material** (c, d) **Combined effect of temperature and light intensity**

Conclusions

The results suggest that the extent of riboflavin and vitamin A photodegradation in milk was dependent on light intensity, exposure time and temperature, depending on packaging material.

References

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