Light barrier properties of paperboard, packages and plastic caps in packages

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Abstract

When light comes into contact with milk, the milk will start to deteriorate and taste bad due to production of off-flavour compounds. Aseptic milk carton packages stored at ambient temperature usually have a layer of aluminium foil, which acts as a barrier for incoming light, water, oxygen and other gases. If the aluminium would not be present the light barrier would mainly consist of the paperboard. In order to develop a milk package without aluminium foil for ambient storage, it is important to obtain knowledge of light barrier properties of paperboard and plastic caps.

When measuring the light barrier in the material two spectrophotometers were used. The spectrophotometers measured the fraction of light that was able to penetrate a sample.

The investigation of paperboards for 1 litre packages showed that they had protection against light of wavelengths that induced off flavour reactions with Riboflavin (220-375, 410-475 nm). But the transmission for light within the range 650-700 nm was above 0.1%. Those wavelengths induce off flavour reactions with porphyrins and chlorins. Different layers in the paperboard contribute differently to the total light barrier of the paperboard. Exposing a paperboard to sunlight deteriorates its light barrier in the long run, while printing on paperboard improves its light barrier.

The plastic caps on packages are a fraction of the total package in term of area. But the light barrier of the total package could be lacking due to the plastic caps which is why they have been investigated. Different colouring pigments give different light barrier properties in the cap.

1. Introduction

For environmental and economical reasons, it is important to make milk packages with as little environmental impact as possible and to reduce the material and energy costs as much as possible. This should be done without losing too much of the protective properties of the packages.

A milk package in general is supposed to protect the product from light, oxygen, moist, migration of odour, loss of aroma and loss of water. [1] Milk is particularly sensitive to light because light has the potential to induce chemical reactions which create off-flavours in milk and because light can degrade some compounds found in milk and thereby deteriorate its nutritional value. [2] This is the case both for pasteurized milk and UHT-milk. [3,4] Milk containing off-flavours has more of a “wet-cardboard” taste, which is generally regarded as unpleasant. [2] Research has shown that a significant amount of consumers are able to detect off-flavours in milk, even if there is only a small concentration of off-flavours in it. [2]

Aseptic packages for milk combine aseptic product with aseptic filling. This type of aseptically packed milk can be stored at ambient temperature for approximately six months. [5] Non aseptic packages for
milk are stored chilled (4°C) and contain the same laminated paperboard as the aseptic package, except it has no aluminium foil, which significantly decreases the light barrier. These packages have a shelf-life of 5-15 days.\(^5\) By storing the product chilled, the deterioration speed of the product is reduced because chemical reactions that induce off-flavours are slowed down by lowering the temperature.\(^2\) Both use of aluminium foil and storage at low temperatures prolong shelf-life and keep product quality but consume large amounts of money and energy. If aluminium is not used the light barrier mainly consists of the carton board and possibly a plastic cap.\(^6\) A milk package without aluminium foil stored at ambient temperature would start to develop detectable off-flavours within hours if there is no other light barrier.\(^2\) It is therefore of importance to obtain knowledge and understanding of light barrier properties in different packaging materials aimed for non-foil milk packages for ambient distribution.

**How light affects milk**

When milk is exposed to light there is a production of flavours that are not favoured by consumers. The main component, responsible for this is Riboflavin (vitamin B2), but also groups of compounds called chlorins and porphyrins may give rise to off-flavours in milk when exposed to light. An example of a naturally occurring chlorin in milk is chlorophyll. Riboflavin, chlorins and porphyrins trigger oxidation of proteins and lipids in milk, when they are exposed to light. These oxidation reactions are what cause the off-flavours to occur. Riboflavin triggers off-flavour reactions when it is exposed to light from 220-375 nm and 410-475 nm. Chlorins and porphyrins trigger off-flavour reactions from 650-700 nm. The International Dairy Federation (IDF) recommends that no more than 2% of the surrounding light at 400 nm and 8% of the surrounding light at 500 nm should penetrate a milk package aimed for chilled distribution.\(^2\) This however is aimed at packaging material for milk at ambient temperature so the minimal light transmission (the amount of light that penetrates a sample) was set to 0.1% instead.

**Purpose of the study**

The purpose of the study was to investigate light barrier properties in paperboard, packages and plastic caps.

2. Material and methods

The study was performed at Tetra Pak packaging solutions AB in Lund from 14 January 2013 to 3 June 2013

Two different spectrophotometers were available when measuring light transmission in a sample. One of them was a dual beam (U-3010) spectrophotometer, used for measuring flat samples and one was a dome spectrophotometer used for measuring light transmission in three dimensions. The samples measured were plastic caps and paperboard. The maximum accepted light transmission for the sample was set to be 0.1%.

**Light barrier in flat paperboard**

Light transmissions of paperboard from different producers were measured in the U-3010 spectrophotometer. The boards were named by its thickness followed by an index A-I, representing the producer. For example 0.26 mm D means the paperboard was 0.26 mm thick and was obtained from supplier D. The maximum accepted light transmission was set to 0.1%. This limit was called the “zero
transmission”, i.e. if a paperboard had less than 0.1% light transmission at a certain wavelength it had “zero transmission”. It was investigated up to which wavelength the paperboard had “zero transmission”.

**Contribution of different layers in the paperboard to the total light barrier**

In order to see how different layers of the paperboards contributed to the total light barrier, paperboards were split into three layers. One bleached top layer (layer closest to the outside of a package), one light brown middle layer and one dark brown bottom layer (layer closest to the product). The light transmissions of the different layers were measured individually and the contribution each layer made to the total light barrier was calculated.

**Printing effect on light barrier in paperboards**

Packages available in market were obtained for this trial. The light transmission of the packages was measured on a non-printed area and a printed area. The results were then compared.

**Light exposure effect on light barrier in paperboard**

Paperboards were exposed to sunlight for a period of a few months. The light transmission was measured once a day in order to see how light transmission changed over time.

**Light barrier in plastic caps**

The light transmission in plastic caps was measured in the dome spectrophotometer. The plastic caps were all of different colours and were supplied by Tetra Pak in Lund.

### 3. Results and discussion

**Light barrier in flat paperboard**

Figure 1 shows a general appearance for how the transmission varies with wavelength for paperboard. The curve is shifted to the left when the light barrier weakens while it’s shifted to the right when it improves.

![Transmission profile for paperboards](image)

*Figure 1. This graph shows the result of a paperboard measured in the U-3010 spectrophotometer. The wavelength of the light is shown on the x-axis and the logarithmic light transmission is shown on the y-axis. Logarithmic scale is used here to easier see 0.1% while being able to see the profile for other wavelengths. The strange peaks below 400 nm are noise which is more apparent at low transmission values.*
As the thickness increases the light barrier improves. This can be seen in figure 2, when comparing the zero transmission wavelengths for different thicknesses from the same producer. There are, however other factors influencing the light barrier which can be observed when comparing the different producers with each other marked with a circle.

![CLC C Duplex, thickness vs largest zero transmittance]

Figure 2. In this graph the largest zero transmission wavelengths have been plotted against thickness. The paperboards were measured with U-3010 spectrophotometer. Since the profile of paperboards transmission doesn’t show any peaks (see figure 32) the zero transmission could be used as a value for barrier property. The different shapes symbolize the different suppliers. Supplier F and J was not included in this graph since they varied with the others by not having a clay coating.

**Contribution of different layers in the paperboard to the total light barrier**

The profile of the different layers is shown in Figure 3. The middle layers barrier was the best among the three layers that the samples were split into. Even though the bottom layer and top layer had about the same thickness their transmission profiles varied. At wavelengths about 600 nm and below the bottom layer has a better barrier while it is worse at wavelengths above 600 nm.

![Transmission of layers after splitting]

Figure 3. A general graph of the light transmission behaviour for the different layers in a duplex paperboard from producer E with 0.38 mm thickness is plotted here. The different layers were separated and measured in a dome spectrophotometer. The top layer had a thickness of 0.127 mm and was bleached with a clay coating. The middle layer had a thickness of 0.255 mm and was brown. The bottom layer had a thickness of 0.121 mm and was darker brown than the middle layer.
The middle layers importance increases with increased total thickness which can be seen when comparing the transmittance from the same producer with different thicknesses, Figure 4. The importance also depends on the composition of the layer because a composition with better light barrier will give larger effect with increased thickness. This is the case since the top and bottom layers thickness are almost constant when the total thickness varies.

Figure 4. The duplex clay coated paperboards layers were split into 3 parts. The top layer consisted of the white part that consisted of bleached paperboard with a clay coating. The middle layer was brown. The bottom layer was also brown but darker than the middle layer. The transmission of the different layers was measured in the dome spectrophotometer. All three layers from the different samples have been included in this graph. The transmission values at 430 nm were used to make this graph. The contribution of each layer was calculated by taking the inverse transmission of the layer divided by the sum of the inverse transmission of all layers.

Printing effect on light barrier in paperboards

The printing colours effect on the light barrier varies with wavelength depending on the pigment used, see figure 5.

Figure 5. The graphs shows the transmission of printed and none printed part of Proviva Skogsbrä. The package were made from a triplex board that consists of a top layer that is white (bleached) a middle part that is slightly yellow (termomechanical pulp) and a white bottom layer (bleached). Measurements were performed in the dome spectrophotometer for wavelengths between 420-760 nm.
**Light exposure effect on light barrier in paperboard**

Figure 6 shows the light transmission on paperboard as a function of time during light exposure. During the first to the second day the light barrier showed an improvement. After that the light barrier weakened and kept weakening beyond the starting point.

![Graph showing light transmission on paperboard](image)

*Figure 6. This graph shows how the transmittance at wavelength 710 nm for a sample changed after being exposed to sunlight by a window for a period of 75 days. The paperboard used was a duplex clay coated paperboard with 0.42 mm thickness. The first couple of days showed a decrease in transmittance. After those days the transmittance increased.*

**Light barrier in plastic caps**

Figure 7 shows light transmission in plastic caps with different colours. Different colours give different transmission at different wavelengths.

![Graph showing light transmission in plastic caps](image)

*Figure 7. Shows the transmission for different coloured plastic caps. Measurements were performed in a dome spectrophotometer for wavelengths between 420-760 nm.*

4. **Conclusion**

Paperboards with a thickness of about 0.4 mm have a light transmission below 0.1% at wavelengths of 500 nm or higher. This means they protect against light that can induce off-flavour reactions with Riboflavin.

The transmission for light within the range 650-700 nm was above 0.1%. Those wavelengths induce off-flavour reactions with porphyrins and chlorins. Since naturally occurring chlorins and phorphyrins
are present in such small concentrations in milk, investigations need to be performed if these compounds have a significant effect on inducing off-flavour reactions and at which light concentration.

The light barrier for paperboard improves with increased thickness. The light barrier for same thickness from different producers varies. This means that there are other factors than thickness that affect the light barrier.

The light barrier for paperboards used for 1 litre packages is mostly located in the middle layer. These paperboards protect against UV light but not against light at wavelength between 650-700 nm which may still give rise to off flavours.

When storing paperboard it should be protected from light in order to prevent weakening of the light barrier properties.

Printing improves the light barrier on paperboard but the effect varies for different wavelengths depending on pigment used.

The plastic caps differ a lot in the light barrier depending on the pigment used. Only the dark brown plastic cap had below 0.1% transmission for all wavelengths between 420-760 nm. This could be used when choosing a coloured plastic cap for milk packages.

References


