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Identification of fatty foods with contamination possibilities by plasticizers when stored in PVC film packaging

Identificação dos alimentos gordurosos com possibilidades de contaminação por plastificantes quando acondicionados em filme de PVC

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Abstract
Poly-(vinyl chloride) (PVC) requires the addition of plasticizers - additives that give flexibility and malleability for its processing into flexible film. The most used ones are: di-(2-ethylhexyl) adipate (DEHA) and di-(2-ethylhexyl) phthalate (DEHP). Toxic effects of DEHP have been observed by several authors. Phthalates are being replaced by alternative substances in PVC flexible products, because of their possible toxicological effects. DEHA is a substitute for phthalates widely used as a plasticizer in PVC materials for involving food. Some authors have shown that the exposure to DEHA also induces toxicity. A cross-sectional study was performed to identify which fatty foods carry the possibility of contamination by DEHP and DEHA. Eighteen different foods with at least 3% (m/m) fat and the possibility of being wrapped in plastic film were determined. This study suggested that all foods were subject to contamination by DEHP and DEHA in those conditions - in decreasing consumption order of 96 to 22% in the convenience sample. New guidelines on the limits of DEHA and DEHP established by the Brazilian legislation, as additives in PVC film for packaging fatty food, are still relevant to ensure human health.

Keywords: PVC; DEHA; DEHP; fatty foods; packaging; toxicity.

1 Introduction

Food quality is directly related to food safety and depends on a range of variables, tangible as well as intangible, which require traceability. The most studied factors that influence the quality of food are the physical, chemical and biological ones, acting on food during the time period from production to consumption (PASCUE, 1996; BARROS, 2005).

The choice of packaging is always related to the product to be packaged (PASCUE, 1996). Packaging materials traditionally used in the market are: glass, paper, metal and plastic. However, in recent decades, the large growth of the plastics industry has encouraged the production of polymeric packaging because they are extremely versatile (AUTIAN, 1980; BRISTON; KATAN, 1974; GILBERT, 1980; ABRANTES, 1998). Poly-(vinyl chloride) (PVC) is one of the used polymers because it can be easily processed and the materials involved in its formulation have a low cost and offer a wide range of properties. The main features that make PVC widely used for packaging food are: transparency, good impact resistance, good barrier properties to gases and water vapor, chemical resistance, and sanitary factors, which allow for consumers external observation of the quality
aspects of products (FERNANDES; GARCIA; PADULA et al.,
1987; NERIN; GANCEDO; CACHO et al., 1992).

The incorporation of additives such as plasticizers, thermal
stabilizers, lubricants, impact modifiers and others is essential for
the processing of PVC resin in the finished product, which gives
the product appropriate specifications for each application. The
typically used plasticizers are adipates, phthalates and epoxidized
soybean oil. The range of plasticizers concentrations used in plastic
is 20 to 40% (m/m) of the polymer mass. The proportion of these
plasticizers is carefully chosen to provide adequate permeability to
oxygen, carbon dioxide and water vapor (FERNANDES; GARCIA;
PADULA et al., 1987; BARROS et al., 2006).

Flexible PVC films are widely used in food packaging as well as
in domestic use and retail marketing. PVC requires
the addition of plasticizers, which are additives that bring
in flexibility and malleability. The most used ones are:
di-(2-ethylhexyl) adipate, DEHA, di-(2-ethylhexyl) phthalate,
and DEHP, which are not chemically bound to the PVC polymer
and, subject certain conditions, may migrate from the plastic
to product that is in contact with the PVC film. Fatty foods
are more likely to absorb these plasticizers, because of their fat
solubility. Toxicity of DEHP has been reported by several authors
(DIRVEN et al., 1993; DOULL et al., 1999; KLIMISH et al., 1992;
DAVID et al., 2000; POON et al., 1997).

The most relevant toxicological effect is due to the
hepatocarcinogenic property of this substance in rats and mice
associated with the induction of hepatic peroxisome
proliferation (DIRVEN et al., 1993). The identification of risk
exposure to DEHP in humans is difficult, because humans and
primates are less sensitive to peroxisome proliferation than rats
and mice (STOTT, 1988). However, in workshop on health risks
caused by the DEHP, participants concluded that this substance
could possibly induce peroxisome proliferation in humans and it
is possibly considered carcinogenic to humans (SCHULZ, 1989).

Recent studies have suggested that DEHP is an endocrine
disruptor (LATINI; VERROTI; DE FELICE et al., 2004). The
endocrine system is a system of hormones that control organism
development, growth, reproduction and behavior. This system
is found in all animals, including humans, and it has three essential
parts: (1) the glands that secrete hormones; (2) the hormones
themselves; and (3) the hormone receptors in each cell. There
are eight types of glands that make up the human endocrine
system: the pituitary; the hypothalamus; the parathyroid; the
thyroid; the thymus; the pancreas; the adrenal; and the gonads
(ovaries in females and tests in males) (TRUSSLE, 2001).

According to Latini (2005), the analysis of biochemical
effects resulting from exposure to DEHP in the levels of
steroid and gonadotroph hormones should be part of a full risk
assessment in human populations.

Although the results are based on a relatively small sample,
which does not have statistically significant evidence, Swan et al.
(2009) suggested that exposure to DEHP and di-(n-butyl)
phthalate, DBP, during pregnancy, could interfere in the
development of the brain, blocking the action of the testosterone
male hormone. The researchers have analyzed urine samples
from pregnant women at the middle of the pregnancy term,
and when their children were 4 and 7 years old these women
were asked to track how their children play. The study found
that boys exposed to high doses of DEHP and DBP during
pregnancy had a lower tendency to play with cars, trains, toy
guns and participate in typically male games, such as fights.
These authors suggested a full investigation under this view.

Because of the possible toxicological effects of phthalates,
they are being replaced by substitutes in flexible PVC products.
The DEHA is a substitute for phthalates widely used as a
plasticizer in PVC for materials involving food. When these
films are in contact with fatty foods like cheese or some
kind of fat meat, there may be a significant migration of DEHA
to food in quantities that exceed the limit of specific migration of
DEHA, 18 mg.kg⁻¹ of food, proposed by the Scientific Committee
for Food of the European Union (DALGAARD et al., 2003).

Silva and Delgado (2007) showed that exposure to DEHA
in utero and during lactation induced mortality in prior and
postnatal offspring, delayed development and caused changes in
specific parameters of the male reproductive system in Webster
mice. They reported a significant reduction of absolute and
relative weight; seminal vesicle; and suggested that the offspring
had been more vulnerable to adverse effects of DEHA during
lactation than during pregnancy.

Grob et al. (2007) showed that for small packs with a high
ratio of contact surface area/volume, present European legislation
tolerates extremely high migration in terms of concentration in
the food, since limits are applied as migration per surface area.
Overall migration limit (OML) may exceed 1,000 mg.kg⁻¹, which
is an order of magnitude above the tolerance for any other type of
food contaminant. With the present rules for specific migration
(SM), the tolerable daily intake (TDI) may be exceeded with less
than 100 g of food, particularly when a fat consumption reduction
factor (FRF) is applied. The OML and the SM of DEHA from PVC
cling films into cheese demonstrated that such high migration is
not just theoretical extrapolation, but it is encountered in reality.
They suggested that the legal limit in terms of concentration
in food should be converted to migration per surface area of
contact - in case of small packages, and the stipulated limit of the
relationship between contact area and volume of food should
suppose 20 dm³.L⁻¹. Then, the proposed OML of 60 mg.kg⁻¹
would correspond to 3 mg.dm⁻². Below that ratio of area and volume,
the value of migration limit should be calculated proportionally
to the surface area of contact, especially for smaller packages.

The National Sanitary Surveillance Agency (ANVISA),
Resolution n. 105 (BRASIL, 1999) establishes the maximum of
3% (m/m) of DEHP in the plastic mass, if the material to get
into contact with foods contained more than 5% fat, and at that
time it did not indicate a restriction to DEHA limit; however, it
indicated a concern with these plasticizers and health. Currently
in force, Resolution - RDC n. 17 (BRASIL, 2008) approves
the “Technical Regulation on the positive list of additives for
plastics intended for production and packaging equipment in
contact with food”, where the specific migration limit (SML),
expressed in mg.kg⁻¹ of simulants for DEHA, is 18 mg.kg⁻¹. In
the case of DEHP, the limit is lower (1.5 mg.kg⁻¹) and only for
use as a plasticizer in materials and reusable objects that are in
contact with non-greasy foods or as an agent for the process at concentrations up to 0.1% in the final product.

The purpose of this paper was to perform a cross-sectional study, through a field survey, for the identification of fatty foods with contamination possibilities by DEHP and DEHA in PVC film packaging.

2 Materials and methods

2.1 Materials

Eighteen different foods were chosen with at least 3% (m/m) of fat in their nutritional composition to determine the main foods for the purpose of standardization in the food questionnaire form (PINHEIRO et al., 1998; FISBERG et al., 2005; PHILIPPI, 2002; INSTITUTO..., 1997) and the packaging possibilities in PVC film, both for domestic use as well as for retail sale.

2.2 Methods

Food survey

The food survey was used as a tool for cross-sectional study in order to obtain the food frequency, the convenience sample and to know how much and which fatty foods with packaging possibilities in PVC films were the most consumed. The sample population was chosen at the Seventh Regional Administration of the State of Rio de Janeiro, which includes the following neighborhoods: ‘Praca da Bandeira,’ ‘Tijuca’ and ‘Alto da Boa Vista.’

Before starting the food survey, participants were told that the objective of the study was to investigate how much and which foods showed on the questionnaire form they consumed. They were told to read an explanation and a consent form advising that all the information collected would be kept strictly confidential and that their names would not appear in any analyses or published reports. They signed the referred consent form. They did not receive any financial help for their participation.

Feeding frequency studies were carried out through interviews according to the food history of each participant and were put in standard questionnaire form, as recommended by (FOOD..., WORLD..., 1995). The studies covered the main foods with packaged possibilities in PVC film, with at least 3% (m/m) fat in their nutritional composition and evaluated the consumption according to Pinheiro et al. (1998), Fisberg et al. (2005), Philippi (2002) and IBGE (INSTITUTO..., 1997), following an experimental design similar to that carried by Abrantes et al. (2005). The standard questionnaire form used for the dietary recall can be seen in Appendix I.

Statistical analysis

Two thousand consumers were interviewed at random, where 41.25 % (825) were men and 58.75% (1,175) were women, respecting the age group, without being obliged to declare anything in writing. To obtain a convenience sample representing a population of 85,100 people aged between 18 and 49 years old, a total of 180,992 inhabitants were the object of the present study (INSTITUTO..., 2008). The sampling plan was used in accordance with NBR 5426 (ASSOCIAÇÃO... 1985) and Abrantes et al. (2005).

The cross-sectional study began in March 2007 with the studies for the preparation of the standard questionnaire form. The interviews took place between May and October 2007 and were held in 4 different large supermarkets in the studied region in different days and times. The questionnaire forms were marked with the possibility of 18 different colors, one for each food, with 126 alphanumeric subgroups, to identify and quantify the frequency of consumption of each food for each subject with scores from zero to six, which represented the absence or the frequency of consumption of each food in the day, week and month as the standardization in the food form (PINHEIRO et al. 1998; FISBERG et al. 2005; PHILIPPI, 2002, INSTITUTO..., 1997).

For this study, the eating score was developed based on the dietary recall, where the food intake was treated as an ordinal variable and received seven values as follows: zero points, when the individual reported that he/she had never eaten that food; one point, when the item was consumed less than once a month; two points, for consumption from one to three times per month; three points, for once a week consumption; four points, for two to four times a week; five points, for once a day; and six points, for twice or more times a day. The total score was obtained by adding up the frequency of each food showed in the food form. The sum of the 18 items constituted the numerator of the preliminary score, in order to consider the items altogether and answer the entire food questionnaire. Thus, estimated the total number of points that each food could have been referred to as the largest food consumption (two or more times a day), among all the items that every person had responded. The preliminary score was then calculated by dividing the points that the food obtained by the total possible points for each case. This concern was relevant, since not all individuals answered to all items. The eating score was calculated by adding the total points scored, divided by the maximum points for each food, according to the number of items completed, multiplied by 100 (FONSECA, 1996; PINHEIRO et al. 1998; FISBERG et al. 2005; PHILIPPI 2002; INSTITUTO..., 1997; LAPPONI, 2001; ABRANTES et al., 2005).

The data were mapped, organized, typed and recorded in Excel Program-Windows and assessed for frequency and amount of consumption in percentage, total and average. Means were compared using the t-Student test and analysis of variance (ANOVA). Estimates of central tendency were also tested using the t-Student test, and differences between proportions by $\chi^2$ test, considering the significance level of 95%. The assurance and the validity of the scores were evaluated using two methods: observation of the correlation coefficients between the items that composed the food score and observation of the correlation coefficients between each item and eating score (GOMES, 1976; COSTA NETO, 1977; SALVINI et al., 1989; RODRIGUES, 1993; VIEIRA, 1988; LAPPONI, 2001; SOARES; SIQUEIRA, 2002;
CALLEGARI-JACQUES, 2004; FISBERG et al. 2005). The field research data analysis was completed in July 2008.

3 Results and discussion

Table 1 was completed according to the answers of each consumer, where the results of the percentage rate of consumption, the total consumption and the average consumption of foods in the study were evaluated. It was observed that, although the mozzarella pizza is in third place on the food frequency, it was the only food with the highest numbers of total consumption, and when it was measured by average consumption, it moved to the first place in this regard.

Because of their fat content, the results showed that there are contamination possibilities by DEHP and DEHA in all foods evaluated in this study, when packed in flexible PVC film, considering that the relevant legislation is not sufficiently clear - not stating the determination of use of DEHP and DEHA, specifically, for fatty foods.

4 Conclusions

The information results compiled and evaluated in the questionnaire form suggested that all foods in the survey which were stocked in PVC film could be contaminated by DEHP and DEHA. We should reflected on the use of these films for food packaging, with technical and scientific criticality, especially regarding the limits set for DEHA and DEHP in our legislation and the government oversight to the matter. Specific laws should state its use in fatty foods and not greasy ones, as well as the respective DEHA and DEHP limits. This study shows the importance of a research that can verify the migration of plasticizers into food, when PVC films are used for packaging. New guidelines on the limits of DEHA and DEHP, as additives in PVC film for packaging foods are still relevant in the multidisciplinary area of the Sanitary Surveillance, so that it can ensure food safety in this regard, therefore ensuring human health. This study is directly linked to the scientific experiment of author in her PhD in Sanitary Surveillance at INCQS / FIOCRUZ.

Acknowledgements

To the National Institute for Quality Control in Health, ‘Oswaldo Cruz’ Foundation (INCQS / FIOCRUZ), Rio de Janeiro, Brazil, and to all its staff and researchers.

References


Appendix I

Ministry of Health
Oswaldo Cruz Foundation - National Institute of Quality Control in Health, Brasil Av., 4365, CEP 21040-900, Manguinhos, Rio de Janeiro, RJ, Brazil

**Food Survey**

*Food Frequency Questionnaire*

Required to be resident of the regional VII Tijuca/RJ

Name (optional):

Sex: ( ) Woman ( ) Man

Income (optional):

<table>
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<th>Foods</th>
<th>Quant.(g)</th>
<th>Never</th>
<th>1 × per week</th>
<th>1 × daily</th>
<th>2 × or + daily (determine)</th>
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<tbody>
<tr>
<td>Minas Cheese</td>
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<tr>
<td>Mozzarella Cheese</td>
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<td>Cheese plate</td>
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<td>Mortadella</td>
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<td>Pork Ham</td>
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<td>Chicken Ham</td>
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<td>Chicken Sausages</td>
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<td>Pork Sausage (raw)</td>
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<td>Lean Beef (raw) - Standard</td>
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<td>Ground Meat (raw)</td>
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<td>Chicken Breast (raw)</td>
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<td>Chicken Wing</td>
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<td>Chicken Thighs Whole (raw)</td>
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<td>Lean Pork</td>
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<td>Fudge Cream</td>
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<td>Mozzarella Pizza</td>
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<td>Simple White Cake Ready</td>
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<tr>
<td>Bulk Butter</td>
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