Design and Development of a Dual Chambered Interactive Juice Packaging for Children

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Abstract

Juice packaging design as a marketing strategy to children is becoming highly sophisticated, increasingly well-funded, and takes place within the environment of other kinds of child-targeted marketing. The joint decision-making process by both parents and children who are the consumers of these products are often influenced by nutritional concerns and price sensitivity for parents while children aim to fulfill spontaneous desires resulting from factors such as visual elements, package image, cartoon characters, colors etc. Even with varieties of innovative juice packaging plaguing our markets today, issues such as little or no user experience, indecisive nature of kids picking just one flavor, and poor shelf life of packaging materials where tiny bit of oxygen penetration results in mold growth and unsustainability are yet to be fully addressed. This paper proposes a juice packaging design solution that adopts polyethylene furanoate material for prolonged shelf life and reduced carbon footprint selected through relative performance index of key features, a dual chambered body design to accommodate both lead and fringe users indecisive nature, a pressure induced closing diaphragm beneath the bottle cap and an interactive labeling for improved user experience in an environmentally responsible way still relatively cheaper compared to current market competitions.

Keywords
Packaging Design, Dual chamber, User experience, Packaging material, Bottled juice packaging

1. Introduction

The role of packaging in a brand's overall communications cannot be over emphasized, particularly as the brand's principal spokesperson within the crowded shopping environment. To maximize its effectiveness for packaging targeted at children, it must exploit the entire pack format using Cartoon Characters, Package image, color, Incentives, and Visual elements. The criteria for developing the optimum packaging design must be based on clear communication of relevant brand values together with appropriate codes and triggers that will aid the purchase decision. Both must be developed with a view to what best fits the consumer's particular shopping mode within a specific market (Clark,1997).

Children find nutritional information confusing and base their healthfulness judgements on visual cues of packages, such as colors or the presence of fruit images (Alejandra et al. 2020). Food packages targeted at children are usually designed using bright colors, cartoon characters, references to fun, sport and play, photos of celebrities, and tie-ins with movies or TV programs. Several marketing techniques are used to target products at children, including advertising, sponsorship, promotions, merchandising, and packaging (Alejandra et al. 2020).

Regarding interactivity versus aesthetics, there exist a gender difference as Interest in a food's interactivity was substantially more pronounced for boys, whereas girls (particularly the older ones generally focus on the aesthetic qualities of food as seen in [G5/6]) controlled experiment in (Clark,1997). This negates a consensus "when things look fancier, they taste worse" as to preferences made by the girl child. Restrictions on marketing strategies of foods targeted at children have been implemented in different countries, but only to a limited extent and not very comprehensive due to misguided marketing strategies that tend to hide information relating to products that contain

excessive amounts of sugar, fat and/or sodium. (Georgina et al. 2013). Nonetheless, the importance of packaging as a key marketing strategy is still very much under-utilized.

1.1. Aim and Objectives

The aim of this work is to design and develop a new juice packaging for children and the specific objectives are:

- present a user- centered, interactive bifurcate juice packaging solution that seeks to address children's indecisive nature in selecting a particular juice flavor allowing then an opportunity to have two flavors that can be taken separately or as a mix
- Ensure a better user experience in the interactivity offered by the bottle cap and labeling. The study also proposes an alternative material to oil-based PET bottle which is not only cheaper, it also has environmental merits being 100% recyclable.

2. Literature Review

We are currently facing an already saturated market of juice packaging products for kids but sadly, many companies rely on subjective judgement - located somewhere between the brain and the gut, with a detour through the heart as suggested by (Clark S.H.L. 1997) rather than user centered approach backed with extensive research on materials and production technology. Food packaging can influence children's attitudes and purchase intentions (Pires and Agante,2011). There is a great diversity of forms of packaging, and designers still hold many possibilities of increasing their number according to the requirements of diverse customers in terms of tastes, traditions, customs, and revenue (Neacşu, 2012). Research has found that licensed characters (Roberto et al., 2010), branding (Robinson et al., 2007), decorative designs (Elliot et al., 2013), and sports celebrity endorsements (Dixon et al., 2014) on packaging influence children's taste and food preferences. Again, the shape of the orange juice bottle has significant influence on choice with anthropomorphic bottle, having the most positive influence compared to round or square bottle shapes (Chitturi et al., 2019) Table 1 presents the state of the art on children juice packaging, outlining: the concept behind the idea; material and production technology; Designer and production year; geographical market location; and dimensions for each understudied product. In comparison, as seen from table 1, products 3 and 4 analyzed, had their design idea generation rooted in a need to solve problems identified from target users in this case, concerned mothers and fruit eating habits respectively, buttressing the point that user-centric design approach meets more easier adoption success as compared to products 5 and 6 having centered ideas in realizing cultural elements.

Table 1: State of Art on Children Juice packaging

S/No	Product Name	Designer and Production year	Concept Idea	Material and Production Technology	Geographical Market	Source
1	New Vision	Xiaowei Lai, Jianzhong Yang, Wei Chen, Ziqiang August 2019	The core idea of packaging design works is to present the rich nutrition of fruit juice through visual graphic design, making it easier for the audience to remember. The design inspiration comes from the colorful life and life. It skillfully applies the computer special effects and printing laser technology to the packaging design. It is a combination of art and technology.	Use computer design software for graphic design. Produced by laser printing process. Bottle height: 220mm Bottle diameter 64 mm	China	https://competition.adesignaward.com/design.php?ID=103664
2	**Yogu-Mogu**	Backbone Branding for *Ashtarak kat 2010*	blending a dairy product with toys (Lady bug and dragon fly). radical and brave proposition – not to tie a personage to the brand but to make a personage out of product packaging.	Bottle height: 220mm Bottle diameter 64mm	Europe	https://backbonebranding.com/works/yogoo-mogoo-yogurt/

3	Moo Goo	Slovenské pramene a žriedla 2012	The task was to help concerned mothers make their kids want to drink milk. At present 3 attractive flavors are produced – caramel, cocoa, and vanilla. The Project commenced with brand name development.		Slovakia	https://backbonebranding.com/works/moo-goo-syrup/
4	Yan Natural Juice Bottle Packaging	Art Director & Designer: Stepan Azaryan, Illustrator: Armenak Grigoryan and Realization: Lilit Arshakyan Backbone Branding 2019	The inspiration lays in the analysis of the fruit eating habits of people either be it by slicing or biting the fruits. The brand of the Yan Natural Juice revolves around the concept of Organic in Everything. Therefore, the bottle was designed based on bio mimicry principles representing bitten apples put one after another which serve as a visual feature for the shape of the bottle. The arrangement of the bottles allows for a significant saving of the pace both on shelves and during transportation.	To emphasize the premium quality and the Eco consciousness of the product, recyclable glass was chosen as a perfect material for storing it. The paper of the label is also recyclable. Width 70mm x Depth 85mm x Height 265 mm The new technology of complementing bottles gives an opportunity for safer transportation compared with the regular cylindrical bottles that are more fragile.	Armenia	https://competition.adesignaward.com/design.php?ID=86906
5	Hou Juice	Design Director: Chen Leng, Designer: Li Yin and Illustrator: Anna rudak 2020	With believe that visual recognition and art direction can give consumers a more reliable sense of brand trust and create a juice brand with a sense of trust and recognition in China. Monkey. The iconic symbol of its parent brand Pagoda fruit, customizes the theme story according to the characteristics of each fruit juice, and presents the natural to one pattern creative style through the form of illustration, which better interprets the concept of nature and freshness of fruit juice brand	The plastic bottle is made of pearlescent film with frosting and spot color printing technology. Diameter 45mm x Height 165mm	China	http://designers.org/design.php?ID=95369
6	Xin You Ran Baijiu	Wen Liu, Rong Mei and Weijie Kang 2019	The design uses Chinese cultural and artistic elements to show a unique effect. The main visual image is a combination of Chinese calligraphy and landscape painting. The use of calligraphy and landscape painting produces cultural inheritance and design innovation. The use of different materials expresses Chinese cultural characteristics. It enhances the artistic sense and uniqueness of the product.	The materials of design are paper, ceramic and wood. The packaging box size is 180mm in length, 150mm in width, 320mm in height.	China	https://competition.adesignaward.com/design.php?ID=89952
7	Pure Juice	Azadeh Gholizadeh Iran 2018	package expresses the effects of fruit extracts, the colorful patterns directly printed on a glass bottle	Glass 55 mm x 55mm x 200 mm	Europe	https://competition.adesigna

			that resembles in the shape of fruits. It visually emphasizes the image of natural products.			ward.com /design.ph p?ID=104 871

3. Proposed Methodology:

Two different research strategies are used to address these packaging problems. The first strategy involves identifying which part of the packaging, i.e. which packaging criterion, should be addressed by using the multicriteria decision making tool. When the most suitable criterion(s) is eventually chosen, more attention was given to these, and through brainstorming during conceptualization phase, target user requirement data made use of from secondary data analysis where all factored in. The second strategy will make use computer aided design software in modelling both two dimensional and three-dimensional representations of the packaging design and development process to make the required changes to the identified criteria while considering sustainable packaging. The proposed models where subjected to structural verification through ANYSYS Workbench software to make sure that technical properties such as weight, strength and hydrostatic pressures are within acceptable limits that ensures manufacturability and usability

4. Material Selection:

By analyzing and comparing the most used materials for fruit juices packaging, also considering the market evolution the most suitable material for the product according to identified key factors were selected.

4.1. Factors considered for Material Choice

Containment: depends on the product's physical form and nature.
Protection: prevention of mechanical damage due to the hazards of distribution
Preservation: prevention or inhibition of chemical changes, biochemical changes and microbiological spoilage
Brand Communication and Information about the product: legal requirements, product ingredients, use etc.
Convenience: for the pack handlers and user(s) throughout the packaging chain.
Economy: for example, cost, efficiency in distribution, production and storage
Environmental responsibility: in manufacture, use, reuse, or recycling and final disposal.

4.2. Commonly Used Juice Packaging Materials:

Aseptic carton: It is made of layers of cardboard (75%), aluminum and LDPE. The cardboard layers give the packaging its shape, the aluminum layer prevents air, light, and micro-organisms from reaching the food and the LDPE layer prevents the food from coming into contact with the aluminum (Mourad et al., 2008)

Glass bottles: It has been and still is a premium material for fruit juices packaging, boasting specific strengths related to hygiene, freshness, and transparency. An additional element on its behalf, is the environmental sustainability since glass is completely recyclable. However, glass requires greater expenses, both when purchasing the raw material and for the transport, since this material is heavier and more voluminous than others. In addition, glass packaging is very fragile and easily breakable.

High density polyethylene (HDPE): This material is used to make bottles for packaging juice and a wide variety of healthcare and cleaning products such as soaps, softeners, etc.

Polyethylene terephthalate (PET): This is used to make bottles mainly for mineral water and soft drink packaging. PET is a recyclable material that is cheap, light, and easy to mold, and that prevents loss of carbonation and flavor (Romero-Hernández et al., 2009). In Europe, PET bottles are available in all sizes.

Polyethylene Furanoate (PEF): PEF has provided a revolution for the packaging industry in the last decade. PEF is a macromolecule like PET in which the terephthalic acid is replaced by another monomer named FDCA, a sugar derived molecule. PEF can improve packaging sustainability since this polymer is 100 % bio-based when BIO-MEG is used in the reaction. Moreover, FDCA is sufficiently like TPA to be used in existing PET polymerization plants, making this technology easily transferable to an industrial scale. (Alaerts et al., 2018). Two of the main companies working on FDCA are Corbion and Synvina, both based in the Netherlands. In the multi-criteria decision-making

context such as ours, a pairwise comparison method was adopted to determine the weighted ranking of alternatives or criteria as shown in tables 2 and 3 below. Kenneth and Betty (2007) identified key factors to consider while selecting a juice packing material as containment, protection, preservation, communication, convenience, economy, and environmental responsibility. In Table 2, pairwise comparison was adopted to determine which of these factors are more significant and should be given more attention and which would receive less attention. Table 3 further matches these factors to the commonly used packaging materials according to their weighted average to select the most suitable material for the Juice bottle.

Table 2: Multi criterion pairwise comparison matrix to determine most important factor to put in consideration and Materials comparison matrix to select material choice

Pairwise Comparison Matrix

=*Much* More Important	=*More* Important	The =*Same*	=*Less* Important	=*MuchLess* Important
9	3	1	0.333	0.111

Criteria		Containment	Protection	Preservation	on and Informatio	Convenience	Economy	onmental responsibility		
	X	1	2	3	4	5	6	7	Total	%
Containment	1	X	3.00	3.00	9.00	9.00	9.00	3.00	36.00	42
Protection	2	0.33	X	1.00	3.00	3.00	9.00	3.00	19.33	23
Preservation	3	0.33	1.00	X	3.00	3.00	3.00	3.00	13.33	16
on and Informatio	4	0.11	0.33	0.33	X	1.00	1.00	0.33	3.11	4
Convenience	5	0.11	0.33	0.33	1.00	X	1.00	1.00	3.78	4
Economy	6	0.11	0.11	0.33	1.00	1.00	X	1.00	3.56	4
onmental respons	7	0.33	0.33	0.33	3.00	1.00	1.00	X	6.00	7
		1.33	5.11	5.33	20.00	18.00	24.00	11.33	85.11	100
		1.6	6.0	6.3	23.5	21.1	28.2	13.3	100	85.11

Table 3: Multi criterion pairwise comparison matrix of commonly used packaging materials in comparison to weighted averages of important factors from table 2

Comprison Matrix

	Criteria	Containment	Protection	Preservation	Brand Communication	Convenience	Economy	Environmental responsibility		
	Weights	0.423	0.227	0.157	0.037	0.044	0.042	0.071		
Options		1	2	3	4	5	6	7	Total	%
Aseptic carton	1	3	3	2	3	1	1	1	2.53	23
Glass bottles	2	3	1	2	1	1	1	3	2.14	19
HDPE	3	2	2	1	2	1	1	1	1.69	15
PET	4	2	2	2	2	2	2	1	1.93	17
PEF	5	3	3	3	2	2	3	3	2.92	26

5. Conceptualization

A bifurcate (dual chamber) interactive Juice packaging for children with visual elements that strikes emotional connection with the child through the “Bunny rabbit” fictional character translated in the bottle cap was proposed. Interactivity intended to be valorized in the way in which the graphical elements communicate with the child in revealing different shades of the juice being consumed with a pressure induced diaphragm for the child’s squeeze effect blended in the cartoon character idea as seen from Good2Grow brand. Through brainstorming value propositions for the bottle design was articulated and presented in Figure 1 below.

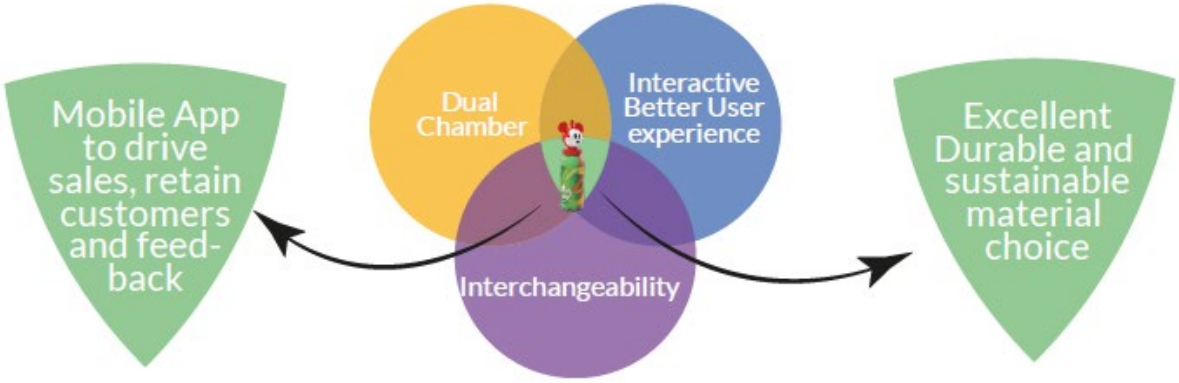

Fig 1. Product concept idea with Unique value propositions

5.1. *Geometrics and Dimensions*

Using SolidWorks, a computer aided design software, 2D representations of the bottle design with proposed dimensions was drawn as shown in Figure 2 with lateral, front, section, top and axonometry drawings.

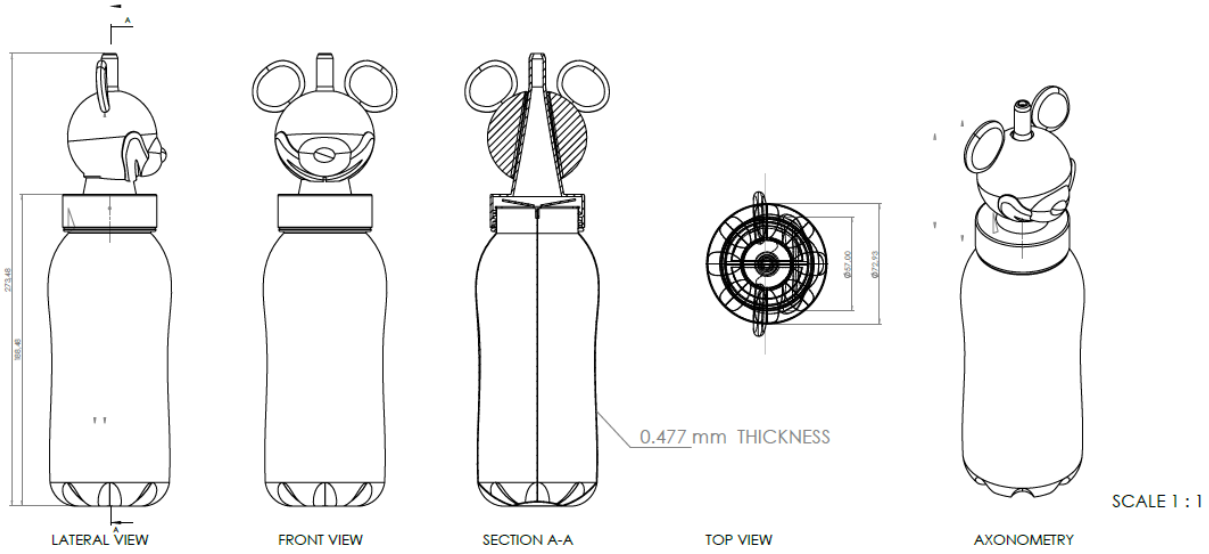

Fig 2. 2D geometrical representations of product with dimensions

5.2. Volumetric 3D Surface Representations

3D modeling and material assignment was done for the bottle design in the SolidWorks software for different components of the packaging design. Images of components and assembly in neutral and rendered forms are shown in figure 3 below.

Fig 3: 3D representation and assembly images of product in neutral and rendered forms

5.3. Structural Analysis

Taking into consideration the standard thickness of PET bottles of 0.5mm and considering the Young Modulus of both PET and PEF, the bottle thickness was optimized at 0.4mm saving material and with ANSYS workbench software we verified total deformation, equivalent stress and strain assuming maximum allowable load and pressure. The result of this simulation is shown in Fig 4 below.

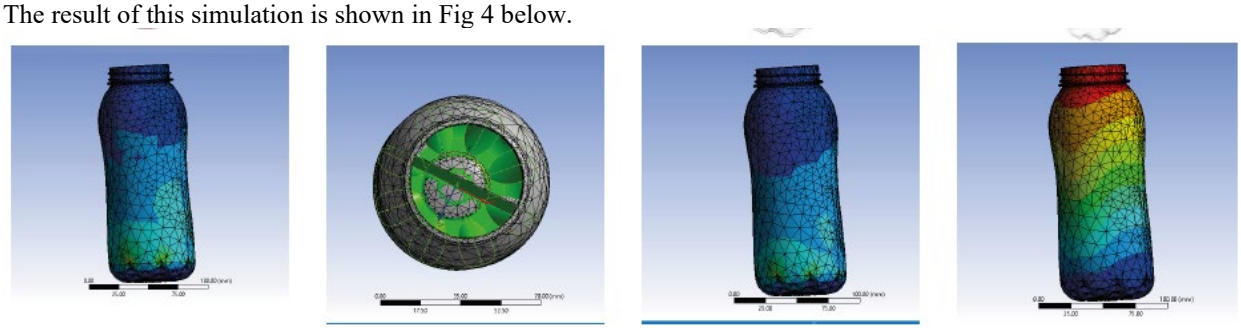

Fig 4: Deformation, Equivalent stress and Strain images from structural analysis on ANSYS workbench

Weight of bottle: 31.06g Volume: 23197mm3 Hydrostatic Pressure: P = rho * g * d =915mm/s2 Maximum total deformation = 526.85mm at bottle neck Maximum equivalent stress = 11982Mpa at base flank Equivalent Elastic strain = 5.26mm

5.4 Cost Analysis

An estimated cost of producing one unit of the juice packaging bottle was analyzed in table 4, price of each component was sourced from unit online prices from Alibaba marketplace as shown in table 4 below

Table 4 List of components used for this product

Component Name	Unit Price	Total cost (€)
Bottle Body	1 kg ≈ 3 €	0.09
Bottle Cap	PLA cap at 2€/ kg	0.19
Diaphragm	0.02€	0.02
Labeling	0.05€	0.05

Same Production process as PET	Estimated Labor and manufacture per unit ≈ 0.13 €	0.13
Total cost of the Product		0.43

5. Conclusion

The aim of this research has been designing and developing a user centric interactive low cost and environmentally friendly juice packaging for children. The dual chambered bottle body made from PEF prolongs shelf life, 4.2 Vol. CO_2 Shelf life to -17.5% (wks), reduces carbon footprint as it is fully recyclable being 100% biobased. Dual chambered also implies that juice producers can now have different kinds of flavors all fitted in one container which helps solve the problem of indecisive nature of kids as to which flavor to forgo as they can now have both choices. The adoption of cartoon character figures in the design of the bottle cap with a pressure induced diaphragm drives home the interactivity between product and target end users which we hoped to achieve.

References

Alaerts, Luc & Augustinus, Michael & Van Acker, Karel. (2018). Impact of Bio-Based Plastics on Current Recycling of Plastics. *Sustainability.* 10. 1487. 10.3390/su10051487.

Alejandra Arrúa, María Rosa Curutchet, Natalia Rey, Patricia Barreto, Nadya Golovchenko, Andrea Sellanes, Guillermo Velazco, Medy Winokur, Ana Giménez, Gastón Ares, Impact of front-of-pack nutrition information and label design on children's choice of two snack foods: Comparison of warnings and the traffic-light system, *Appetite,* Volume 116, 2017, Pages 139-146, ISSN 0195-6663, https://doi.org/10.1016/j.appet.2017.04.012. (https://www.sciencedirect.com/science/article/pii/S0195666316309254)

Chitturi, R., Londono, J. C., & Amezquita, C. A. (2019). The Influence of Color and Shape of Package Design on Consumer Preference: The Case of Orange Juice. Int. J. Innov. Econ. Dev, 5, 42-56.

Clark S.H.L. (1997) How packaging works with children. In: Smith G. (eds) Children's Food. Springer, Boston, MA. https://doi.org/10.1007/978-1-4613-1115-7_7

Dixon, H., Scully, M., Niven, P., Kelly, B., Chapman, K., Donovan, R., Martin, J., Baur, L.A., Crawford, D. and Wakefield, M. (2014), Child responses to food pack promotions. Pediatric Obesity, 9: e47-e57. https://doi.org/10.1111/j.2047-6310.2013.00169.x

Elliott CD, Carruthers Den Hoed R, Conlon MJ: Food branding and young children's taste preferences: a reassessment. *Can J Public Health*. 2013, 104 (5): e364-e368.

Elliott, C. (2009). 'Healthy food looks serious': How children interpret packaged food products. Canadian Journal of Communication, 34(3). 359-380. http://hdl.handle.net/1880/50208

Georgina Cairns, Kathryn Angus, Gerard Hastings, Martin Caraher, Systematic reviews of the evidence on the nature, extent and effects of food marketing to children. A retrospective summary, Appetite, Volume 62, 2013, Pages 209-215, ISSN 0195-6663, https://doi.org/10.1016/j.appet.2012.04.017. (https://www.sciencedirect.com/science/article/pii/S0195666312001511)

Jorgelina Pasqualino, Montse Meneses, Francesc Castells, The carbon footprint and energy consumption of beverage packaging selection and disposal, *Journal of Food Engineering*, Volume 103, Issue 4, 2011, Pages 357-365,ISSN0260-8774,https://doi.org/10.1016/j.jfoodeng.2010.11.005. (https://www.sciencedirect.com/science/article/pii/S026087741000542X)

Pires, C. and Agante, L. (2011), Encouraging children to eat more healthily: The influence of packaging. *J. Consumer Behav.*, 10: 161-168. https://doi.org/10.1002/cb.362

Neacşu, Andreea. 2012. Designul şi estetica ambalajului – element de marketing.Braşov: *Editura Universităţii Transilvania* din Brasov

Roberto CA, Baik J, Harris JL, Brownell KD: Influence of licensed characters on children's taste and snack preferences. *Pediatrics*. 2010, 126 (1): 88-93. 10.1542/peds.2009-3433.

Robinson TN, Borzekowski DL, Matheson DM, Kraemer HC: Effects of fast-food branding on young children's taste preferences. *Arch Pediatr Adolesc Med*. 2007, 161 (8): 792-797. 10.1001/archpedi.161.8.792.

A' Design Awards, Available: https://competition.adesignaward.com/design.php?ID=103664, Accessed on June 3, 2021.

A' Design Awards, Available: https://competition.adesignaward.com/design.php?ID=86906, Accessed on June 3, 2021.

A' Design Awards, Available: https://competition.adesignaward.com/design.php?ID=89952, Accessed on June 15, 2021.

A' Design Awards, Available: https://competition.adesignaward.com/design.php?ID=104871, Accessed on June 26, 2021.
Backbone Branding, Available: https://backbonebranding.com/works/yogoo-mogoo-yogurt/, Accessed on June 26, 2021.
Backbone Branding, Available: https://backbonebranding.com/works/moo-goo-syrup/, Accessed on June 26, 2021.
Designers.org, Available: http://designers.org/design.php?ID=95369, Accessed on June 26, 2021.

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