Design and Development of Sustainable Soft Toys: A Transformation towards Bio and Circular Economies

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Abstract —**Soft toys or Stuffed toys are favourites of not only young children but also teenage girls and women. Many children around the world have soft toys that they play and sleep with. Studies have shown that soft toys can have a positive effect on a child's development. On the other side soft toys are a known source of house dust mites (HDMs) and their allergens. As children often sleep with soft toys close to their airways, any allergens present thereon could be a potential problem for sensitized asthmatics. Synthetic fabrics and filling fibres used in soft toys manufacture are non-biodegradable and lead to serious environmental hazards including micro fibre pollution. Most soft toys are difficult to wash and disinfect. This study aims to make soft toys with natural fibres that are biodegradable. The toys are designed in a way that it comprises of two parts in which the outer part is detachable from the inner part. The outer part could be washed easily while the filling fibres are stuffed in the inner part. The developed soft toys were tested for safety by standard test methods. Pre and post surveys have been conducted among people to know the opinion and feedback of the developed soft toys.**

Index Terms — **biodegradable, eco-friendly, entrepreneurship, natural fibres, plush toys.**

I. INTRODUCTION

The Textile and Clothing industry is one of the most important manufacturing industries in the world. The environmental impacts of the textile industry take account of air, water and land pollution at an alarming rate. In addition, the occupational health hazards of the workers and the consumer health are also at risk. Textiles used for children are manufactured with utmost care to avoid any hazardous substances in it. Mouthing in children is one important behaviour that has been identified to expose them to environment chemicals. Babies and young children frequently mouth objects, including toys, resulting in saliva mobilization and oral exposure to toxic chemicals [1]. A stuffed toy is a toy doll with an outer fabric sewn from a textile and stuffed with flexible material. They are known by many names, such as plushies, stuffed animals, plush toys, or stuffies. The toy originated from Germany in the late 19th century and gained popularity following the creation of the teddy bear in 1903 [2]. Soft toys or Stuffed toys are favourites of not only young children but also teenage girls and women. Many children around the world have soft toys that they play and sleep with. Studies have shown that soft toys can have a positive effect on a child's development. Even in today's technological age, soft toys still line the shelves of shops all over the world and are one of the most loved toys.

Soft toys can provide the perfect mix for developing sensory skills and encouraging social and emotional growth of babies and children [3].

Soft toys are a known source of house dust mites (HDMs) and their allergens. As children often sleep with soft toys close to their airways, any allergens present thereon could be a potential problem for sensitized asthmatics. Mites are small arthropods belonging to the class Arachnida and the subclass Acari (also known as Acarina). Respiratory allergies including bronchial asthma are caused by the inhalation of dead or live mites or their products, more importantly their faecal content [4].

Hard toys are less contaminated, easier to clean, and do not recontaminate as rapidly as soft toys. It was found that hard toys could be effectively decontaminated by cleaning and then soaking them in a hypochlorite (2.5 g/l) solution for one hour. We did not investigate shorter soak times. Machine washing and drying soft toys was found to be inadequate, with high bacterial counts present after cleaning. However,

disinfecting by soaking soft toys in a hypochlorite solution for 30 minutes, followed by machine washing and drying, was found to reduce bacterial counts and eliminate coliforms [5].

A study found soft toys to be a potential source of not only HDM but also allergens from cat and dog even in homes with no cats or dogs. Sensitized asthmatic children exposed to these kinds of allergens could be at a significant risk of increase in morbidity [6].

Mite allergens accumulate rapidly in toys to form a potentially important source of allergens and washing toys with a chemical detergent is effective in the reduction of allergens [7].

Twenty-four children's toys and child care articles available in the local market of India were analysed for eight phthalates as children's toys are plasticized with phthalates. All toy samples showed the presence of one or more phthalates including di-(2-ethylhexyl) phthalate (96% of the samples), di-iso-nonyl phthalate and di-iso-decyl phthalate (42% of the samples) at a concentration ranging from 0.1% to 16.2%. Soft toys contain higher levels of phthalates as compared to hard toys as primary function of phthalates is softening of hard plastic material [8].

Soft toys are a major source of house dust mites (HDM) and HDM allergens, and sleeping with soft toys is a significant risk factor for HDM sensitization. Three techniques to eliminate HDM from soft toys, namely freezing, hot tumble drying and washing with eucalyptus oil were studied. Thirty-six toys (12 in each treatment group) were enumerated for live HDM by the heat escape method before and after freezing overnight, hot tumble drying for 1 h and washing in 0.2% to 0.4% eucalyptus oil. Freezing, hot tumble drying and washing with eucalyptus oil resulted in significant reductions in live HDM, an average reduction of 95.1%, 89.1% and 95.1%, respectively. Additionally, washing with eucalyptus oil resulted in a significant reduction in HDM allergens as well from a geometric mean of 9.12lg/g to 0.37lg/g ($p = 0.033$) [9].

A study by Costa et al. [10] evaluated the different cloth types and padding used in the manufacture of toys and the performance of these tissues during the processes of hospital hygiene. The toys were submitted to varied hospital's disinfection processes after contamination with different microorganisms (MO): Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa and Candida krusei, main agents found in human microbiota. The toys suffered slight deformation after passing through different hospital's washing processes. Toys submitted to light and heavy washings showed no significant deformation. The application of disinfection products did not change the overall structure of the toys. The microbiological evaluation after washing not demonstrated effective removal of MO inoculated.

Soft toys making is a good choice of women entrepreneurship in India. It creates employment opportunities for many women. It is suitable for uneducated women [11].

II. MATERIALS AND METHODS

A. Materials

The materials used for soft toy making and the specifications are given in Table 1. Bio-degradable natural fibres have been chosen as the filling material. The Velcro and zipper used were of good quality that can be sent to recycling by the end of life of the toys.

Table 1 Materials used for making soft toys

S. No.	Material	Specification	Application
1	100% cotton 3 thread fleece (loop knit) fabrics	GSM ranging from 200 to 300 Thickness ranging from 0.8 to 1.9 mm	Outer fabric layer of soft toys
2	100% cotton plain woven off-white fabric	EPIxPPI: 72x66; 30s Ne; 58″ Width; Areal density: 100 g/m^2; Thickness: 0.213 mm	Inner fabric layer of soft toys
3	Loose fibres	•Banana fibre (from sheath) •Banana bract fibre •Banana core stem fibre •Corn husk fibre •Kapok fibre •Polyester fibre (used only for comparison)	Filling / Stuffing material for soft toys
4	Cotton embroidery thread	Mercerized cotton thread	Hand sewing of outer fabric

5	Velcro tape	Hook and loop type	Fastener for soft toys
6	Zipper	Plastic	Fastener for soft toys

Bio-degradable natural fibres used as stuffing for soft toys and their chemical composition and physical properties are given in Table 2. The images of the fibres and their source are shown in Figure 1.

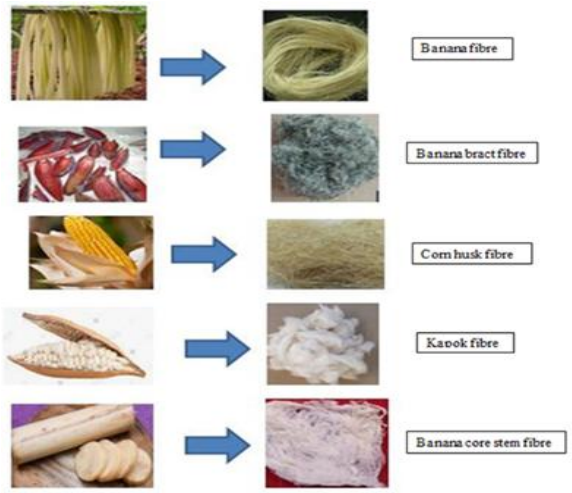

Figure 1 Natural fibres selected as filling for soft toys

Table 2 Stuffing fibres used for making soft toys

S. No.	Material	Physical properties	Chemical composition (%)	Reference
1.	Banana fibre	Tensile strength 700-800 Mpa Young's modulus 27-32 Gpa Density 1.35 g/cc	Cellulose 60-65 Hemicellulose 6-8 Lignin 5-10 Ash 1.2 Moisture content 10-12	[12] [13]
2.	Banana bract fibre	Fiber length 22 to 33 cm Diameter 79.6 µm Breaking strength 60.1 gf Tensile strength 178.17 Mpa Elongation 20.9% Young's Modulus 2.99 GPa Density 1.39 g/cc	Cellulose 56.48 Lignin 5 Wax content 1.05 Moisture content 10-11	[14]
3.	Corn husk fibre	Diameter 0.186 mm Tensile strength 160.49 Mpa Elongation 21.08% Young's Modulus 4.57 GPa Density 1.49 g/cc	Cellulose 46.15 Hemicellulose 33.79 Lignin 8.92 Moisture content 7.9	[15]
4.	Kapok fibre	Length 16.32 mm Width 17.59 µm Cell wall thickness 1.34 µm Density 0.29 g/cc	Cellulose 38.09 Lignin 14.10 Wax content 2.34 Ash 1.05 Moisture content 11.23	[16]
5.	Banana core stem fibre	Density 0.98 g/cc	Cellulose 62.24 Hemicellulose 15.23 Lignin 18.51 Ash 5.03 Wax 0.29 Pectin 2.00 Moisture content 11.53	[17]

B. Design and Making of Soft Toys

The soft toys are designed with two layers such that the inner layer contains the stuffing fibres and the outer layer that could be easily removed and washed. All the fabric materials used are cotton and the filling materials are natural fibres that are biodegradable. Velcro tape or Zipper has been used as fasteners and no other sharp objects or plastics are used as eye/nose of the soft toys. All the toys are handmade and the eye, nose, mouth is made with fabrics. Soft toys such as teddy bear, dolphin, octopus, minion, owl, turtle, rooster, puppy face, fish, Christmas tree, ice bar were developed (Figure 2).

Figure 2 Photographs of developed soft toys

It is easy to make as double layers for certain toy models and difficult with other models. Even teddy bear has been made as two layers. The weights of dolphin toys with different filling fibres have been calculated and showed in Table 3. It is found that the corn husk fibre was the lightest followed by polyester and banana core stem fibre. But the problem with corn husk fibre is its rough texture. Hence the study suggests banana core stem fibre would be a suitable alternative filling material in soft toys.

Table 3 Weight of the dolphin toys made with various filling fibers

Filling Fibre	Filling wt. (g)	Outer fabric wt. (g)	Inner fabric weight (g)	Total (g)
Polyester	106	53	16	175
Banana	142	55	14	211
Banana bract	165	54	15	234
Corn husk	101	55	16	172
Kapok	147	53	15	215
Banana core	127	52	11	190

C. Testing and Evaluation

The developed soft toys are tested for the following parameters:

• IS 9873 (Part 1): 2019 Safety Aspects Related to Mechanical and Physical Properties
• IS 9873 (Part 2): 2017 Flammability
• IS 9873 (Part 3): 2017 Safety of toys - Part 3 Migration of certain elements

D. Survey

The author conducted two online surveys through Google Forms, one before the development and the other after the development of soft toys, and one (face-to-face) questionnaire survey to get the feedback about the developed products.

Table 4 Survey details

Survey No.	Mode	Total number of respondents
1	Online (Google Forms) Before the development of soft toys	109
2	Online (Google Forms) After the development of soft toys	146
3	Face-to-face (Questionnaire) Final opinion survey	100

III. RESULTS & DISCUSSION

The safety of the soft toys tested by IS 9873 – parts 1, 2 and 3 have passed as shown in Table 5.

Table 5 Safety testing of soft toys

Test Standard	Test name	Inference	Conclusion
IS 9873 (Part 1): 2019	Safety Aspects Related to Mechanical and Physical Properties	Normal use, reasonably foreseeable abuse, material, small parts, points	Pass
IS 9873 (Part 2): 2017	Flammability	Did not ignite	Pass
IS 9873 (Part 3): 2017	Safety of toys - Part 3 Migration of certain elements	Selenium and heavy metals such as Antimony, Arsenic, Barium, Cadmium, Chromium, Lead, Mercury were not detected	Pass

The inference of Survey 1 (Google forms) conducted before the development of soft toys is given below:

Interpretation:

•54.4% of the respondents' family have single child.

•38.2% of the respondents use a soft toy for more than 4 years, 30.1% use for about 2 to 4 years while 31.7% use less than 2 years.

•12.9% of the respondents have at least 10 soft toys at home.

•59.2% of the respondents buy soft toys occasionally while 13.6% buy frequently.

•Safety & Convenience is the major deciding factor while buying soft toys as opted by 44.8% of the respondents while 28% look for special features in soft toys.

•49.2% of the respondents wash the soft toys once in 3 to 6 months while 20.5% wash once in 6 to 12 months; 24.6% wash rarely and 5.7% never wash the soft toys.

•24.8% of the respondents feel that the care and maintenance of soft toys is difficult; 32.0% said maybe and 43.2% felt it easy.

•79.2% of the respondents are aware of the fact that soft toys cause respiratory allergy in children.

•70.4% of the respondents are aware of the fact that commercially available soft toys are non-biodegradable thereby leading to environmental pollution.

•76.8% of the respondents are willing to buy eco-friendly soft toys.

•58.4% of the respondents are willing to pay extra for eco-friendly soft toys; 24.8% may be willing and 16.8% are unwilling.

•46.8% of the respondents donate the soft toys after use; 34.7% throw in the garbage; 15.3% send for recycling.

The inference of Survey 2 (Google forms) conducted after the development of soft toys is given below:

Interpretation:

•98.1% of the respondents say washing and disinfecting soft toys is important.

•44.9% of the respondents rated excellent and 52.6% good for the soft toys made with two layers.

•94.2% of the respondents are aware of the microfiber pollution caused by synthetic fibres.

•49.4% of the respondents rated excellent and 44.9% good for using cotton fleece fabric for soft toys.

•67.9% of the respondents rated excellent and 27.6% good for using natural fibres as fillers for soft toys.

•67.5% of the respondents rated excellent and 33.3% good for the developed soft toys.

•60.3% of the respondents rated excellent and 33.3% good for the sustainability of the soft toys.

•55.1% of the respondents are willing to pay extra for sustainable soft toys; 35.3% may be willing and 9.6% are unwilling.

•52.6% of the respondents rated excellent and 44.9% good and 2.6% fair for the overall outcome of the study.

The inference of Survey 3 conducted after the development of soft toys is given below:

Interpretation:

•96% of the respondents like the developed soft toys.

•48% of the respondents' home possess more than 3 soft toys; 15% has 3; 23% has 2; 4% has 1 and 10% do not possess any soft toy.

• 69% of the respondents find it difficult to wash the soft toys.

•53% of the respondents rated excellent; 40% good and 7% fair for the soft toys made with two layers.

•51% of the respondents rated excellent; 54% good and 5% fair for the use of natural fibres as filling material for soft toys.

•59% of the respondents chose Kapok; 26% Banana bract; 21% Banana core; 11% Corn husk; and 7% Banana sheath fibre as the most suitable filling material for soft toys.

•65% of the respondents rated excellent; 33.3% good and 2% fair for the developed soft toys.

•65% of the respondents liked dolphin the most; 32% octopus and 24% liked other soft toys.
•66% of the respondents rated excellent and 34% good for the developed soft toys.

IV. CONCLUSION

Eco-friendly and sustainable soft toys have been developed to promote the wellness of the consumer and the environment. The soft toys passed the physical and mechanical tests, flammability test and also no harmful chemical substances were detected in any of the materials used. Hence the toys are safe for children of all ages. The investigator received very good feedback from the respondents who took part in the online and offline surveys. The outcomes of the project would benefit the environment as well as the economy by creating employment opportunities for household women. Agro-residual fibres could be effectively used in soft toys industry.

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