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EFFECT OF FILLER CONTENT ON THE MECHANICAL PROPERTIES OF DATE PITS POWDER FILLED FLEXIBLE POLYURETHANE FOAM

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Abstract

The main target of this research is to use readily available material as filler in the production of flexible foam. An agricultural waste Date pits at 40µm size were incorporated into the formulation of polyurethane foam with different loading of 5, 10 and 15 (%). The effect of date pits powder on mechanical, thermal, physical properties and visible test was investigated and recorded. The results showed that the hardness and density properties increased as the filler loading increases, however the values unfilled foams were lower than that of the filled samples with value from 121 - 143 (shore A) for 5% - 15% respectively and 19.33 - 22.58 (cm^3) for 5% - 15% respectively. The result showed that 5% loading gave the highest temperature and compression resistance with values of 164 (° C) and 54.86 (AC %) respectively, the visible test result deduced different color for 0%, 5%, 10%, and 15% loading (white color foam, light brown foam colour, dark brown foam colour, dark brown foam colour) respectively, therefore the date pits can be used as filler in the production of polyurethane foam for added values.

Keyword: polyurethane foam, date pits and mechanical properties.

INTRODUCTION

Foam is a substance that is obtained by the entrapment of gaseous bubbles into a liquid or a solid (Lucassen, 1981). These gaseous bubbles are separated by a sheet known as lamellae. When the lamellae are thick, spherical bubbles are formed but when it is thin, polyhedral bubbles are formed. The polymeric materials known as polyurethanes form a family of polymers which are essentially different from most other plastics in that there is no urethane monomer and the polymer is almost invariably created during the manufacture of a particular object.

Solid foam is formed when gas is blown through solidifying plastic. Depending on its ability to retain original shape after compression, it can be classified as either flexible or rigid, Isa *et al.,* (2012). The foam can either be closed or open cell foams. In closed cell foams, the foam cells are isolated from each other while the open cells foams are made up of broken cell walls, (Babalola and Dominic, 2012). Flexible polyurethane (PU) foam is one of the major production from urethane material. Flexible polyurethane foams are used as cushioning material for automotive seat, mattress, and furniture and in packaging etc.

Calcium carbonate ($CaCO_3$) often utilised as filler by mattress factories in the production of polyurethane foams. It allows the substitution of part of the polymeric agents, conferring dimensional stability and hardness to foams.

Calcite (Calcium Carbonate) holds the largest market volume and it is mainly used in plastic industries. Other fillers includes Dolomite ($CaMg(CO_3)_2$), kaolin and talc (Hans, 2005). The use of inorganic fillers have several disadvantages including difficulty of preparing and maintaining the dispersion problems with removal of entrained air, difficulty of mixing and pumping the filler/polyol slurry, loss of the foam physical properties, difficulty of processing on all types of foam machinery and due to their abrasive nature, increased wear on machinery components (Bartczaket *et al.,* 1999).This research work is aimed on the study of the effect of date pits as a filler on the mechanical properties of a flexible polyurethane foam.

High cost of raw materials used for the production of polyurethane foam especially polyol and isocyanate, demands sourcing for a cheaper, readily available and eco – friendly mineral that can be used as fillers.

Mineral calcium carbonate ($CaCo_3$) Holds the largest market volume in the plastic sector and is mainly imported. Hence, the need to source for renewable materials, which can serve as alternative fillers to the conventional mineral calcium carbonate ($CaCo_3$) with a view of minimizing the polyurethane foam production cost. And the date pits disposal poses a significant challenge to these industries in this time of increasing environmental safety which have necessitated the need to utilize these date pits as fillers by polymer industries.

The driving force of this research is use date pit in the foam production if established will provide means of cleansing the environment of pollution problem which the date pits constitute and also provide an alternative use for the date pits

MATERIAL AND METHODS

Table 1: Materials, Equipment, Chemicals and Additives

S/N	MATERIALS	EQUIPMENTS	CHEMICALS AND ADDITIVES
1	Pails	Standard mesh sieve (pore size 40μm)	Polyol
2	Cups		Water
3	Stirrer	Digital weighing balance (model AD01)	Silicone oil
4	Mould	Griffengrund hot oven	Dimethyl Ethanol Amine
5	Respiratory mask	Compression tester	Tin or Stannous Octaote
6	Laboratory coat	Hardness testing machine (shore A)	Toluene diisocyanate (TDI)

7	Measuring	Date – pits powder (filler)
8	Hand gloves	
9	Stop watch	

METHODS

PREPARATION OF DATE-PITS POWDER

Date-pits were washed, dried at 90 – 95° c and then ground to fine powder in a pulverizing mill. The powder was then passed through a 40um standard mesh sieve and dried again in an oven to constant mass in order to ease dispersion in the foam matrix. The formulation table used for samplen1 which is the flexible polyurethane foam with no reinforcement with $CaCo_3$ and 2, 3, 4 are the flexible polyurethane foam reinforced with Date- pits powder shown below in table 1 and table 2.

Table 2: Formulations

S/N	**CHEMICAL**	PPHR (%)	**WEIGHT (g)**
1	Polyol	100	1000
2	Water	4.84	48.4
3	Silicone oil	1	10
4	Dimethyl Ethanol Amine	0.18	1.8
5	Tin or Stannous Octaote	0.14	1.4
6	Toluene diisocyanate (TDI)	58.8	588

Production of foam

The polyether polyol was weighed into a container and the ground date–pits were added. This was followed by stirring for about 15 seconds to obtain uniform dispersion. The other ingredients were respectively added to the dispersion starting with silicone oil, stannous octoate amine and water. Every ingredient added, stirring period of about 10 seconds was also taken with a stop watch. This process was repeated for the different weights of filler. Ten minutes after full rise was attained, the foam samples were removed from the mould and allowed before the next addition. Toluene di- isocyanate (TDI) was weighed and poured into the polyol mixture and stirred for about 10 seconds. The mixture was immediately transferred into the mould with dimensions of 8 x 8 x 8cm and the rising time (time taken to attain full height) to cure for 24 hours before Characterization. This was also repeated for the different foam samples based on their gram weight.

ANALYSIS

Foam interior temperature determination

As stated earlier the polyurethane (CPU) foam production reaction is exothermic, thus the temperature profile needs to be studied. To avoid scorching of the foam the maximum temperature allowed for PU is 170°C.

In this test a thermometer was inserted in the foam and the temperature profile at different time intervals was noted and the results given in table 6.

Density determination

The density of the foam produced was obtained by taking mass and the volume using a metre rule, digital weighing balance and a calculator of the various samples and results calculated using the formula Shown below:

$$\text{Density } (\varrho) = \frac{\text{mass (m) kg}}{\text{Volume (v) m}^3} \quad (1)$$

Compression test

This test was conducted on the foam to know the rate at which the foam can regain its thickness after a deforming force or load has been removed.

The test was conducted by putting a small rectangular Piece of the sample into the compression set and was compressed to 75% of its original height (h) for 72 hours.

After this, the sample was removed and allowed to rest for 45 minutes. The new height (h_1) of the foam was recorded and the rate of compression calculated using the formula below:

$$\text{Compression} = \frac{h_0 - h_1}{h_0} \times 100 \qquad (2)$$

Hardness test

This test method is intended to provide a quick and simple method to screen flexible polyurethane foams for determination of its firmness grade. Instruments and materials used in carrying his tests are; Stop- watch, Indentation hardness tester, Calculator, Biro and paper.

Visibility test

Sample of each of the foam was exposed to light to see its reaction and any other observation was also taken down.

RESULTS AND DISCUSSION

Peak temperature

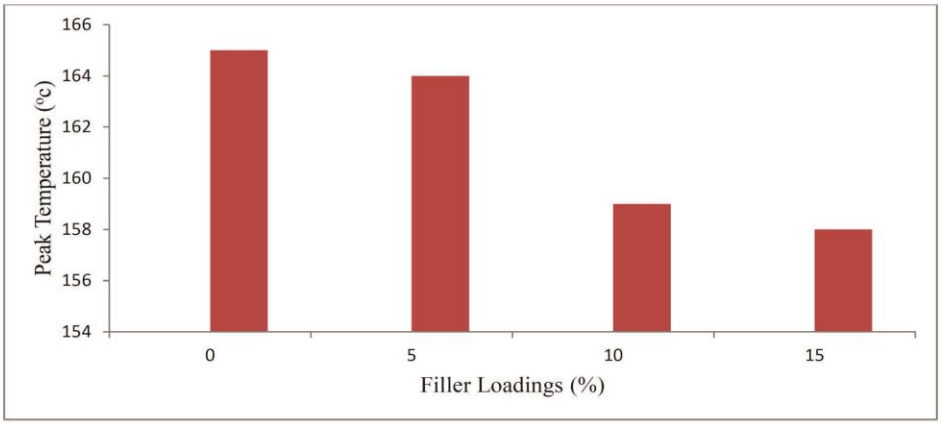

Figure 4.1 Effect of Filler Loading on Temperature of polyurethane foam / Date pits particles.

From the graphical representation, it was observed that the temperature rose to a peak and declined i.e. from 165° c to 159° c and then 158° c. with the value of the peak temperature lower than 170° c, it can be said that, the foaming temperature was within the acceptable or considerable range and therefore no risk of foam scorching or fire outbreak. This scenario obtained goes in line with Jimoda (2021) findings.

Density

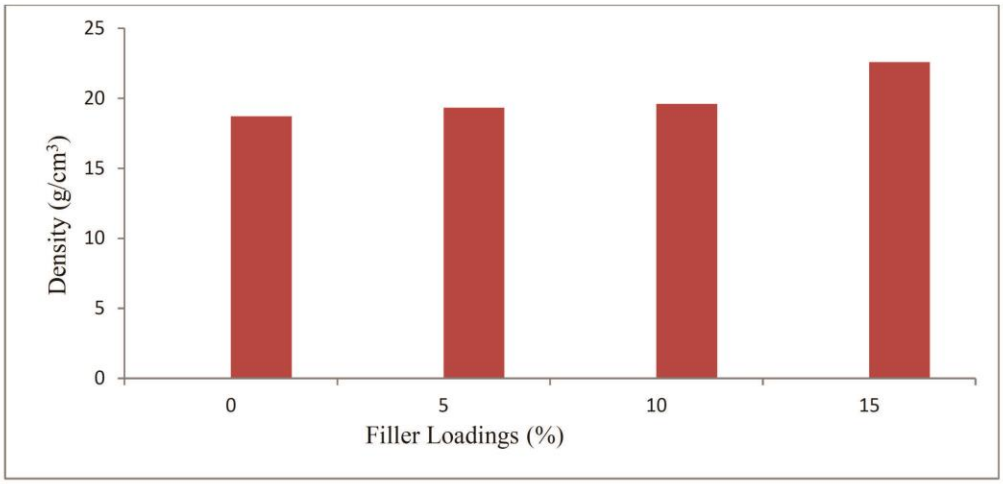

Figure 4.2 Effect of Filler Loading on Density of polyurethane foam / Date pits particles

From the graphical representation shown in figure 4.2, it was observed that, the foam density increases as the filler loading increases from 5%- 15% with values of 18.71 (kg/m³)- 22.58(kg/m³) respectively. This is within the range for flexible polyurethane foam 13-80 kg/m³ .Also, it implies that the foam produced is a medium duty foam (MDF) using the industrial standard grade scale. According to the results, it can be said that, the foam has a compact cell structure and a good load bearing ability. The results correspond to the findings.

onugbu *et al.,* (2013).

Hardness

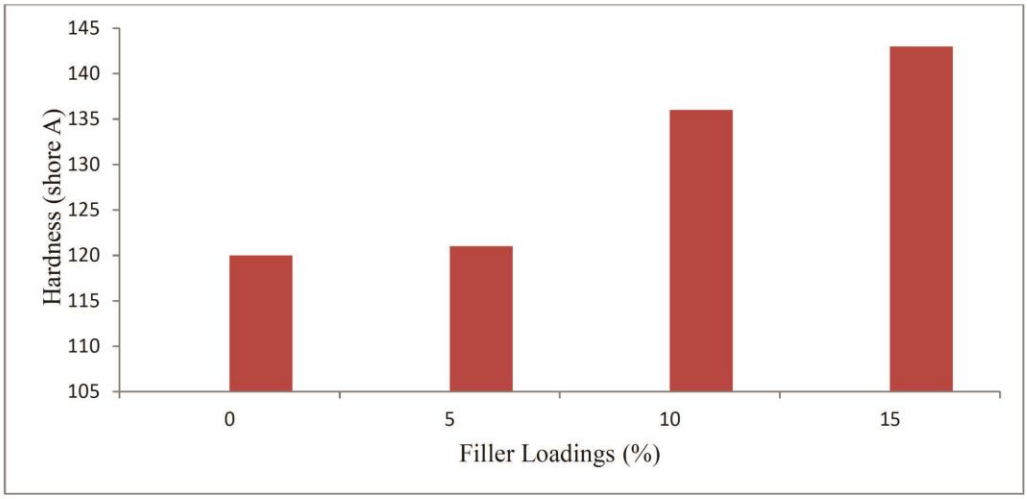

Figure 4.3 Effect of Filler Loading on Hardness property of polyurethane foam / Date pits particles

From the results obtained in figure 4.3, generally, the hardness result values increase as the filler content increases from 5% - 15% filler loading with 121N - 143N, however 0% loading had lesser hardness value compared to filled samples. These results showed that the foam has a considerable raising factor or capacity. The trend obtainer aligned with Okeke *et al.,* (2020).

Compression

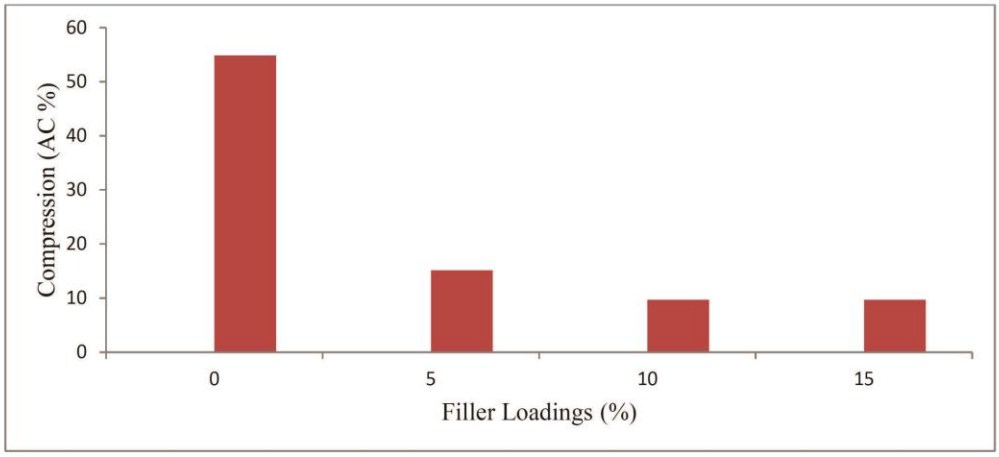

Figure 4.4; Effect of Filler Loading on Temperature of polyurethane foam / Date pits particles

The results obtained from the graphical representation of compression test, it showed that, the foam has good elastic properties i.e. figure 4.4 showed a good potential of regaining its original height after a deforming force is removed. The compression set test is a measure of hysteresis to loss of energy due to irreversible deformation when the foam is subjected to compression to decompression cycle. Smaller compression value implies smaller hysteresis and invariably lesser susceptibility of the foam to suffer irreversible deformations.

VISIBILITY TEST

From the results obtained from the visibility test, it was observed that sample 1 (0%), reaction was fast with a setting/curing time of 1min 14secs given a white colour foam.

Sample 2 (5%),reaction was a bit slower compared to sample 1.It has a choky smell, hot eyes, setting /curing time of 1min 30secs given a light brown foam colour.

Sample 3 (10%), reaction is slow, the filler introduced is a heat absorber to the reaction, the higher percentage of the filler, the higher the output. Therefore, it caused cracking on the foam sample, the setting/curing time is 2mins 04sec giving a dark brown foam colour.

Sample 4 (15%), the rate of reaction is inversely proportional to the percentage excess of the filler generates heat in the reaction process. Setting/curing time is 2mins 10secs giving a dark brown foam colour.

CONCLUSION

This study shows a successful production of flexible polyurethane foams creating a better

means of disposing challenges to our environment. The incorporation of date pits as a filler enhances its density, hardness, compression and temperature of the polyurethane foam. These test shows gradual improvement. The mechanical properties such as hardness, density, temperature and compression were influenced by the filler loadings (5%, 10% and 15%) offering better fibre-matrix interface adhesion and increase in mechanical properties.

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