PRODUCTION OF DATE-SEED ACTIVATED CARBON FOR USE IN ADSORPTION REFRIGERATION APPLICATION

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ABSTRACT
High energy requirement of vapour compression refrigeration systems necessitate the increasing need for more reliable, flexible and cost efficient cooling systems alternatives. Energy saving potential, Carbon emission reduction and waste heat utilization of adsorption refrigeration system could be exploited in this regard. Some of the setbacks that hinder adsorption refrigeration systems from real mass production and commercialization can be address by the development of relatively low cost, available and suitable adsorbent materials. This research work seeks to locally produce date-seed activated carbon and test its adsorptive properties for possible application in adsorption refrigeration system. Physico-chemical analysis was carried out using standard established procedures. The average pH-level, porosity, bulk density and iodine number were found to be 9.43, 62.25%, 0.41g/cm^3 and 1075mg/g respectively. The Date-seed activated carbon was found to have relatively good adsorptive characteristic in addition to its availability and relative low cost and therefore could be used as adsorbent in refrigeration system.

Keywords: *Adsorption refrigeration, Physico chemical analysis, Date-seed, Activated Carbon*

Introduction

Relative high energy requirement of vapour compression cooling systems and environmental considerations further necessitate the increasing need for more reliable, flexible and cost effective cooling system alternatives. Energy supply to refrigeration and air conditioning systems constitutes a significant percentage of energy consumption in our world. In 1988, the International Institute of Refrigeration (IIR) estimated that approximately 15% of all electricity produced worldwide is used for refrigeration and air conditioning processes of various kinds (Suleiman, 2011). Over population and hence increase in thermal comfort/process requirements and global warming keeps this value on the increase. In 2012, a study shows Refrigeration and air conditioning systems consumes around 30% of total worldwide energy consumption (Ahmed, 2012).

Currently, most of the world energy demand for refrigeration and air conditioning is met by mechanical vapour compression systems driven by high-grade electrical power input and utilizes environmentally harmful refrigerants. Vapour compression systems still dominate almost all application areas (Ahmed, 2012). Adsorption refrigeration systems could be a better option in terms of huge energy saving potential, Carbon emission reduction and waste heat utilization. In addition, they have a higher reliability because it has no moving parts (Mahmod and Ahmed, 2015). Adsorption refrigeration system uses solid adsorbent that adsorb and desorb a refrigerant vapour in response to changes in the temperature of the adsorbent (Li, *et al.,* 2007). Adsorption refrigeration system is however characterized by low coefficient of performance (COP), and hence the strong need to explore other means of improving the general performance of the system for continuous and effective operation.

Li and Wang (2007), identified certain disadvantages which hinder adsorption refrigeration system from real mass production and commercialization. These includes: (i) Long adsorption desorption time; (ii) Small refrigeration capacity per unit mass of adsorbents, i.e. low specific cooling power (SCP); and (iii) Low coefficient of performance (COP). Work is therefore focused on three main aspects: (i) To apply new cycle which can recover more heat; (ii) To improve the adsorbent bed by enhancing the heat and mass transfer in the adsorbent; and (iii) To develop new adsorbent material (Li, *et al.,* 2007).

Figure 1 and Figure 2 shows a typical adsorption refrigeration cycle and a Clapeyron diagram of the ideal adsorption cycle respectively.

According to Alghoul, *et al.,* (2007), the important considerations influencing the choice of a suitable adsorbent are:

i. Adsorption of large adsorbate under low temperature conditions to yield good COP.
ii. Desorption of most of the adsorbate when exposed to thermal energy.
iii. Possession of high latent heat of adsorption compared to sensible heat.
iv. No deterioration with age or use.
v. Non-toxic and non-corrosive.
vi. Low cost and availability.

Considerations (i) and (ii) tend to be mutually exclusive, although while Activated carbon seems to strikes the best compromise. Other adsorbents materials includes: Silica-gel, Zeolite, Activated-alumina, Calcium chloride, Metal oxide etc.

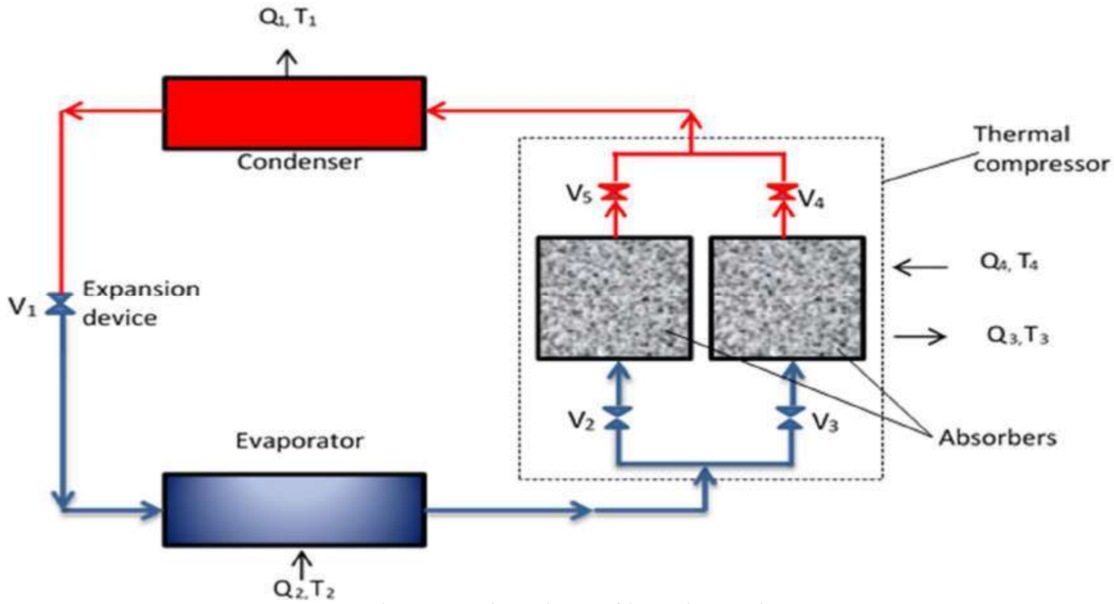

Figure 1: Adsorption Refrigeration cycle

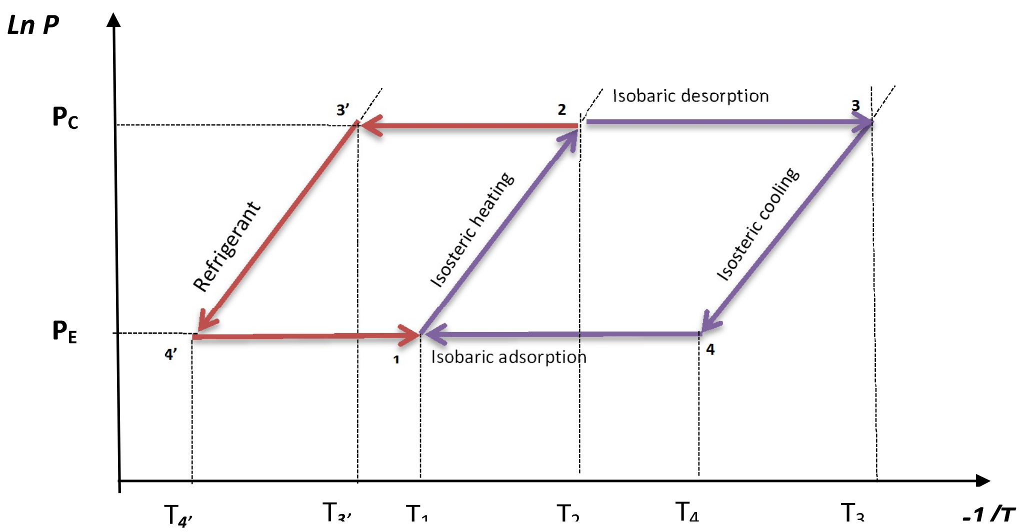

Figure 2: Clapeyron diagram of the ideal adsorption cycle (Suleiman, 2011)

The Date palm (phoenix dactylifera. L) locally called Dabino as shown in Figure 3 has been an important traditional crop and a staple food of the Middle East and some part of the world for thousands of years. Under average conditions, date-seeds are burned to yield about 60% parts by volume, or 25% parts by weight of charcoal (FAO, 2014).

The aim of this research is therefore to produce and analyse the adsorptive properties of Date-seeds Activated-carbon as an adsorbent for use in adsorption refrigeration applications. This is achieved through the following specific objectives to:

i. produce activated carbon locally using date-seeds.
ii. determine the pH, porosity, bulk density and amount of iodine of both the activated and non-activated date-seeds carbon using Physico-chemical analysis.

Figure 3: Date-seeds (FAO, 2014)

Materials and Method

Materials

Date fruits were collected from local market in Zaria, Nigeria. The seeds were removed from the fruits, washed thoroughly with water, cut into smaller bits, rinsed with distilled Water, air-dried and later oven dried at about 100°C for 6hrs. The oven dried date-seeds sample were carbonised. Part of the carbonised samples (DSC) were activated to obtain the date-seeds Activated-carbon (DSAC). Commercial Activated-Carbon (CAC), Maxsorb III and chemical activation reagents ($ZnCl_2$, HCl, NaOH and NH_3) were acquired from a scientific store in Kaduna, Nigeria.

Six samples were prepared and grouped into A and B. Group A consists of two samples A□ and A□ from the conventional activated Carbon (Maxsorb III). Group B consists of four samples B□ B□ B□ and B□. B□ and B□ are non-activated Carbon produced from date-seeds while B□ and B□ are activated Carbon produced from the date-seeds.

Methodology

Carbonisation and Chemical Activation

Carbonisation was carried out (Sodeinde, 2012) using a muffle furnace for 2hrs at a temperature of 650°C to produce carbonised date-seeds (DSC). Chemical activation of the date-seeds carbon (DSC) was carried out in accordance with Sodeinde (2012). The specimen was soaked in chemical solution of $ZnCl_2$ for 8 hours, it was further treated with HCl (0.1M), NaOH (1M) and Ammonia solution. The moist activated carbon was placed in the furnace again at 700°C (activation temperature) to increase the porosity of the activated carbon. The resulting date-seed activated carbon was washed with distilled water and dried in the furnace for 2hrs at a temperature of about 110°C.

Adsorptive properties test

The standard test method for the determination of activated carbon pH (ASTMD3838-80) was adopted, bulk density and porosity (Ekpete and Horsfall, 2011) was used, also, the amount of iodine adsorbed was determined using the procedure of Abdul-Halim *et al.,* (2001).

Discussion of Results

Preliminary Proximate Analysis Result

Comparative analysis of the experimental results obtained from the preliminary proximate analysis (for date-seed carbon) with results obtained by other researchers for carbons prepared from different bio-materials is presented in Figure 4.

The result obtained for DSC showed a low amount of moisture, relatively low ash content and moderate volatile content. DSC appears to have the best compromise, suggesting that the particle density is relatively small and that the biomaterial has the potential of being an excellent raw material for adsorbent production for use in adsorption refrigeration system. Ash content affects activated-carbon in reducing the overall activity of the substance (Donau-Carbon, 2012). It also reduces the efficiency of reactivation, the lower the ash content value therefore the better the activated-carbon for use as adsorbent. Presence of volatile content (impurities) such as metallic salts, in the presence of moisture, leads to corrosion. Metals usually react with water to produce corrosion.

Comparative analysis of the experimental results obtained from Date-seed activated carbon with results obtained by other researchers for activated carbons prepared from different bio-materials is presented in Figure 5

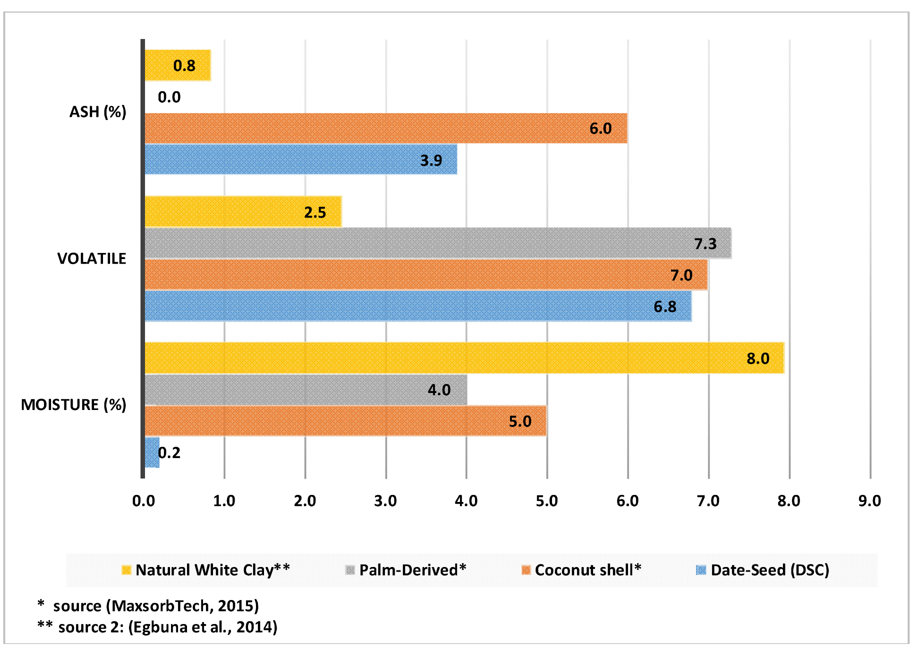

Figure 4: Comparative analysis of the properties of Carbon produced from different bio- materials

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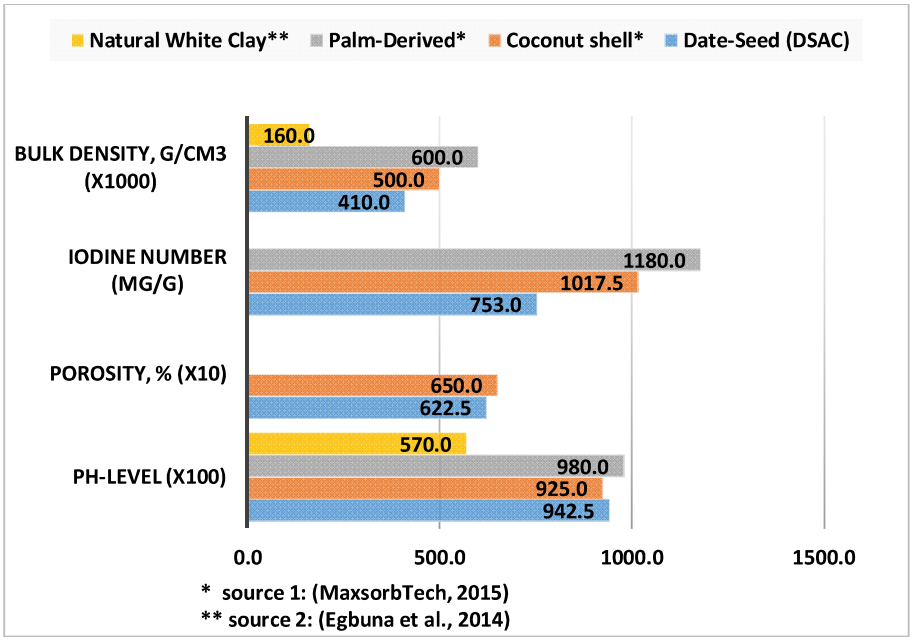

Figure 5: Comparative analysis of the Physico-chemical properties of different activated carbon

Palm derived activated carbon appears to have the highest Iodine adsorption capacity (1180), however it's pH-level (9.8) is far beyond the acceptable limit (9.1 - 9.5). Besides, palm derived carbon recorded a poor bulk density. CAC and DSAC with pH-level 9.25 and 9.42 are more preferred than Palm derived [pH limit for adsorbent: 9.1 – 9.5 (MaxsorbTech, 2015)]. The bulk density results obtained for DSAC (0.41) as compared to the result obtained for CAC (0.58) suggests that DSAC adsorption system has the potential of being more compact and flexible in nature.

Also, Physico-chemical properties of CAC, DSAC and DSC are compared and presented in Figure 6.

The comparative analysis shows a significant increase in the rate of iodine adsorption of DSC from 458 to 753 when activated. This amount (753) for DSAC is below the value recorded for CAC (1075), it is however within the acceptable limit [iodine number ≥ 400mg/g (John, 2014)] indicating tendency of DSAC to adsorb and desorb adsorbate in response to temperature change. Size of adsorber bed for DSAC system can be slightly increased to obtain equal particle mass per unit volume with CAC system. In most situations (with some few exceptions), bulk density is inversely related to the porosity of a substance, the more porous the substance the lower the value of the bulk density (John, 2014)

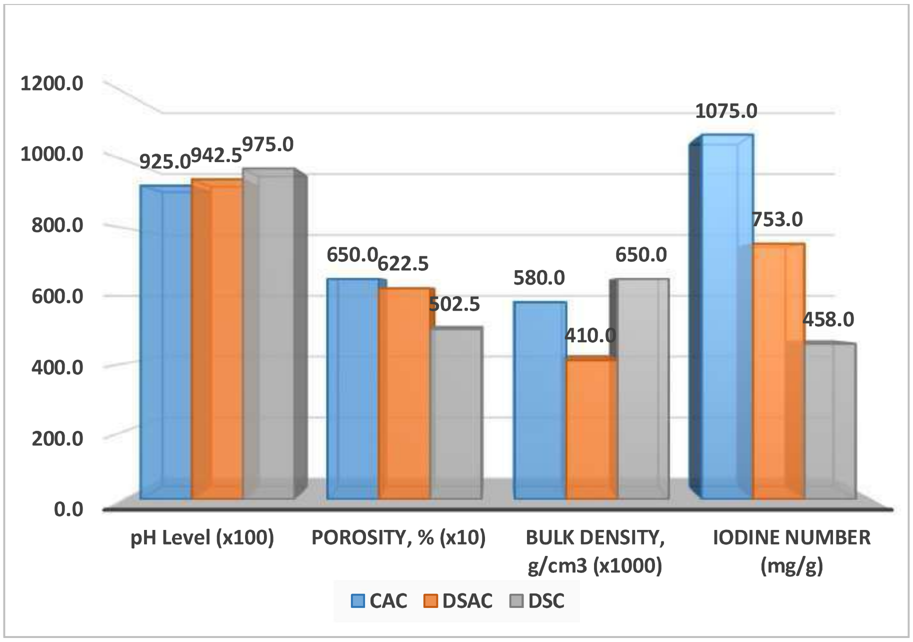

Figure 6: Comparative analysis of the Physico-chemical properties of CAC, DSAC and DSC

The porosity value recorded for CAC and DSAC are about 65 % and 62 % respectively. This appears to have slightly deviated when compared with the values of bulk density recorded. This may be attributed to the relatively lower particle mass per unit volume of DSAC than CAC.

Conclusion

Date-seed activated Carbon was produced locally. This was preceded by preliminary investigation which suggested that Date-seed Carbon could be a potential adsorbent in adsorption refrigeration system. The resulting activated carbon was characterised by its pH-Level, Porosity, Bulk density and Iodine number using adopted standard established procedures. With its relative low cost and availability, the activated carbon produced was found to have relatively good adsorptive characteristic and therefore could be used as adsorbent in refrigeration system.

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