Design, Fabrication and Performance Evaluation of an Indigenous Honey Extractor

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Abstract
Honey is the most important primary product of beekeeping both from a quantitative and an economic point of view. It was also the first bee product used by human kind in ancient times. The history of the use of honey is parallel to the history of man and virtually every culture evidence can be found of its use as a food source and as a symbol employed in religious, magic and therapeutic ceremonies is an appreciation and reference it owes among other reasons to its unique position until very recently, as the only concentrated form of sugar available to man in most parts of the world. The same cultural richness has produced an equally colorful variety uses of honey in other product. Because of these important reasons, honey used to be extracted (collected) to meet the demand both in raw form or as valued added to other products. The economic and medicinal importance of honey warrants the development of low cost, locally made and portable extractor that can be accessed by the honey farmers. The availability of this machine will increase honey production into the market, relief the honey farmers of their drudgery in producing honey, create self employment for the jobless and finally increases the economy of Nigeria through exportation of this honey and its products. The physical characteristics (viscosity, density, hyroscopicity; surface tension) and thermal properties of honey were considered before the design and fabrication of this extractor. The design was made simple and manually operated which can be installed at home or farm where breeding of honey bees is possible. It is a chain driven system with sprockets of small diameter of 55 mm and big diameter 343 mm and teeth number of 18 and 113 respectively with chain pitch of 99.525mm of type number 150D/N=06B-2Rdon DR957. The chain system was mounted on a vertical central solid shaft of diameter 25 mm to this shaft was the honey comb net bucket of hexagon shape with six segments was welded. A full turn will give the net bucket housed in a cylindrical container (drum) speed of 200 rpm when loaded. While the design driven force is 0.7054N. The volume of honey collected was 9.0 litres while the one collected from imported honey extractor was 11.0 litres when 15 kg of honey comb was used to fill their net baskets under the same number of turns. This proved the local fabricated extractor to be 82% relative efficient. The cost of production was twenty five thousand (25,000) naira only which is one hundred and sixty US dollars ($155.28) equivalent of current exchange rate of 161 Naira per US dollar. This amount took care of bought out component, machining, non machining, and material costs with 10% profit margin. The only limitation is that it is not electrically driven, has the advantage of being used in both urban and rural areas where there is no electricity.

Keywords: development, honey extractor, performance evaluation, honey, economic values.

INTRODUCTION
Honey is the natural sweet substance produced by honey bees from the nectar of blossoms or from the selection of living parts of plants or excretions of plant sucking insects on the living parts of plants, which honey bees collects, transformed and combine with specific substances of their own, store and leave in the honey comb to ripen and mature in which all commercially required characteristics of the production are described. Honey in this research referred to the honey produced by Apis mellifera. Honey is used in moisturizing and nourishing cosmetic creams but also in pharmaceutical preparations and also applied directly on open wounds, sorbed sores, ulcers, varicose ulcers and burns. It helps against infections promotes tissue regeneration and reduces scarring also in its pure, unprocessed form (Biesmeijer, 2003).

Weaver and Weaver (2000) further emphasized that honey improves food assimilation and is to be used for chronic and infective intestinal problems such as constipation, duodenal ulcers and liver disturbance. A lot work has been done on honey therapy by Schneider et al, 1998 and Sammataro and Aiphonse, 1986). The tropical applications under controlled conditions have shown underrated wound healing in animals (Richard, 1990) and of experimental burn wounds in rats but also of various types of wounds including post operation ones in humans (Thorpe et
al, 1971). Honey can be made dried or dehydrated by various industrial techniques by including inclusion in some recipes (Sanford, 2000). Dried honey (Thorpe et al, 1971) described to be hygroscopic and needs to be stabilized by mixing other powders such as starches, flours or other non hygroscopic sugars. This can be made to a powdered honey which can be used in dry mixes for cakes, breads, and drinks or energy health powders and avoids the need to handle any liquid or sticky honey. KAK, 2001 discusses the use of dried honey in baked goods in Germany. Krell (1996) describes different production techniques used in Turkey to stabilized dry honey powder. Hoopingerner, 2001 reports granular dried honey as reducing shrinkage of meat products by 19% and production of an additive free dried honey powder has been mentioned in the speedy bee (1988). Because of these aforementioned benefits derived in honey, its extraction is very important to make it available for its unlimited demands. Almost 20 years ago, industrial consumption of honey was only 5 to 15% of total honey consumption (Krell, 1996). This proportion has increased in the meantime and is expected to continue increasing considering the advantageous consumer appeal of products with honey as an ingredient.

It is possible to enjoy extracted honey without recourse to machine extractor, using basic kitchen implements to cope with one or two supers. It will be time consuming, sticky and inefficient, but if it means that her beekeepers family can obtain some benefits from his or her obsession, it will be worthwhile.

Series of extractor have been developed in advance countries e.g. United States, Germany, Australia, Italy and other such extractors as tangential, radial, automatic programmable and electrical driven types (Sammarato and Alphonse, 1986). A fortunate beginner will not be able to buy the types mentioned above because of their costs. In addition to the above, if intending to purchase, the choices faced are tangential or radial? Plastic or Stainless steel, manual or electric driven? Therefore, there is need to developed in portable hand driven radial type extractor of low cost used for commercial purpose with its material locally sort for and electricity which its supply is irregular was considered.

**METHODOLOGY**

Investigating the physical characteristics of honey was carried out as for viscosity, water content, density, effect of temperature change, specific gravity, hygroscopicity, surface tension colour and crystallization and composition of honey from literature. Biesmeijer, 2003; Harriott et al, 1970; Hoopingerver, 2001; Krell, 1996; Schneider, 1998; Richard, 1990); FAO,(1986). Rodriguez Lapez, (1985) and (White et al, 1962) did sufficient research in these areas.

**Machine Description**

The developed extractor was made of axial solid shaft carrying the chain driving system on its top accommodations, the small sprocket and the bearing top most part of the shaft. This solid shaft also accommodate the hexagonal shaped basket (six segments to accommodate the matured honey comb ready for honey extraction. While the whole mechanism was housed in a galvanized cylindrical container for honey collection and evacuation.

**Material Selection**

The axial shaft was mild steel and silver painted after coated with anirrust paint. The basket as well as the cylindrical container were made of galvanized flat bars and sheet metals respectively. After the welding process, the welding lines were coated with anirrust and silver parts. These decisions were taken to avoid rust which can contaminates the honey and to reduce cost of production compared to high cost of stainless steel.

**DESIGN ANALYSIS**

These major components were designed: chain drive, power transmitted, load on the shaft, force required and diameter of the axial shaft.

**Design Analysis of the Chain Drive:** The selected chain pitch is (9.525mm) of the type number 150/DSN=06B-2 Rolon DR 957. The specification of the chain selected 06B-2 Rolon DR 957 are: pitch, (P)=9.525mm, maximum roller diameter (D)=6.35 mm, minimum width between inner plates (W)=5.90 mm, maximum diameter of pin body (D)=3.28 mm, maximum depth of the plate, (D)=8.18 mm, the transverse pitch,(P)=10.24 mm, maximum overall joint,A1-A2-A3=26.60 mm, bearing area (B)= 0.56 cm², weight per meter (W)=0.77 Kg, minimum breaking load (B)=1730 Kgf, the speed ratio (i)= 6.3 and from the table, the selected number of teeth, Z1 = 18.

(a) **Determination of Sprockets Number of Teeth**

The number of teeth for the wheel sprocket bigger sprocket, (Z2)

\[
Z_2 = Z_1 \tag{1}
\]

Where: \( Z_2 \) = number of teeth of wheel sprocket, 
\( Z_1 \) = number of teeth on pinion sprocket while \( i = \) the speed ratio= 6.3 from data: This gave \( Z_2 = 113 \) teeth.

(b) **Determination of Sprocket Diameters Pinion and the Wheel.**

Pinion = \( d_1 = (P/\sin (180/Z_2)) \tag{2} \)

(Hall et al,1983)

Where \( d_1 \) = diameter of the pinion sprocket.
\[ \sin 180^\circ = \text{angle of inclination}, \ P = \text{pitch of the chain and} \ Z_2 = \text{number of teeth on the (pinion) sprocket}. \] 
The calculated \( d_2 = 54.90 = 55 \text{mm} \) 

(c) **Determination of the Wheel diameter:**

The diameter of the larger sprocket (wheel) \( d_2 = \left[ \frac{P}{\sin(180/Z_2)} \right] \) 

Where \( d_2 \) = diameter of the larger sprocket, \( P \) = pitch of chain, \( \sin 180^\circ \) = angle of inclination of chain and \( Z_2 = \text{number of teeth on the wheel sprocket} \) and \( d_2 = 343 \text{mm} \)

(d) **Determination of the Service Factor \( K_s \):**

This was determined using the formula \( K_s = K_1 K_2 K_3 K_4 K_5 K_6 \) (3) 

(Lipson et al., 1960) 

Where \( K_s = \text{service factor} ; \ K_1 = \text{load factor} ; \ K_2 = \text{factor for distance regulation} ; \ K_3 = \text{factor for center distance of sprocket} ; \ K_4 = \text{sprocket position factor} ; \ K_5 = \text{lubrication factor} \) and \( K_6 = \text{rating factor} \). The calculated service factor (\( K_s \)) was 2.34

(e) **Determination of Pinion \( (n_2) \) Speed:**

The speed of the pinion \( n_2 \) 

Predetermined speed for wheel \( n_2 = 32 \text{ rpm} \) 

Therefore from: 
\[ Z_2 n_1 = Z_2 n_2 \] (4) 
\[ n_2 = \frac{Z_2 n_2}{Z_1} \] (5) 

Where \( n_1 = \text{speed of pinion} \) and \( Z_2 = \text{number of teeth of pinion} \). The calculated \( n_2 = 200 \text{ rpm} \)

(f) **Determination of Power Transmitted \( P_t \):**

(i) The design for power transmitted was based on breaking load. 
\[ N = QV/102n_1K_2 \] (6) 

(Lipson et al., 1960) 

Where \( Q = \text{breaking load} ; \ V = \text{chain velocity in m/s} \) 
\( n_1 = \text{speed of the pinion} \) and \( K_2 = \text{service factor} \). The \( N = \text{power transmitted} = 0.54 \text{KW} \).

(ii) The tension due to the sagging of chain, \( P_z \) 
\[ P_z = K_z W a \] (Hunt, 1974) 

where: \( P_z = \text{tension due to sagging of chain, Kgf} ; \ K_z = \text{coefficient for sag} ; a = \text{center distance in m} \) and \( W = \text{weight for meter of chain, Kgf} \). The computed \( P_z = 1.32 \text{ Kgf} \)

(iii) The centrifugal tension, \( P_c \) determination.

\[ P_c = \frac{W V^2}{g} \] (8) (Hunt, 1974) 
Where: \( P_c = \text{centrifugal tension, Kgf} ; W = \text{weight per meter of chain, Kgf} ; V = \text{velocity of chain, m/s} \) and \( g = \text{acceleration due to gravitational pull in m/s}^2 \). By computation the centrifugal tension, \( P_c = 0.026136 \text{Kgf} \)

(iv) The tangential force due to power transmission, \( P_t \) 
\[ P_t = 102N/V \] (9) (Thurman and Paul, 2006) 
Where \( P_t \) = tangential force, \( N = \text{Newton} \) and \( V = \text{velocity of the chain, m/s} \) while the tangential forces, \( P_t = 94632.48 \text{Kgf} \)

(v) The designed power transmitted, \( P_t \) 
\[ P_t = P + P + P \] (10) (Thurman and Paul, 2006) 

The power transmitted \( P_t = 8.87 \text{ Kgf} \)

2.3.2 Determination of Load on the axial shaft \( Q_o \). 
\[ Q_o = K_s P_2 \] (11) 

Where \( K_2 = \text{load factor selected from data} \) and \( P_2 = \text{calculated tangential force} \).

The calculated load \( Q_o \) on the shaft 108827.35 Kg.

2.3.3 Determination of the driving force on the shaft 
\[ P = F \times V \] (12a) 
\[ F = P/F \] (12b) 

The drawing force was determined to be 0.71 (N)

2.3.4 Determination of the diameter of the axial driving shaft, \( d \) 
\[ D^2 = \frac{16S_2[(K_b M_b)^2 + (K_c M_c)^2]}{112} \] 

Where \( S_2 = \text{shear stress} ; K_b = \text{combine shock and fatigue factor applied to bending} ; K_c = \text{combine shock and fatigue factor applied to tension} ; M_b = \text{bending moment} \) and \( M_c = \text{tensile moment} \) \( d = 25 \text{ mm} \)

**Production Cost**

The cost of production of this machine covered: bought out components, machining, materials and non machining costs. This was estimated to be twenty five thousand naira (N25, 000) only. A profit margin of 10% was given this made the selling price to be twenty seven thousand five hundred naira (N27, 500) only

**Performance Evaluation of Extractor**

In order to evaluate the level of performance of this extractor, it was installed in Sunshine Honey Production Unit of Ondo State Ministry of...
Agriculture along Ondo road Akure through the permission of the unit authority. Experiments were conducted by loading the honey extractor with the honey combs of 2.5 kg in each segment which is of total six segments which accommodates a total mass of 15 kg of honey combs. These experiments were conducted between July 7 and September 17, 2010. The results of this experiment is as shown in Table 1. Comparing the quantity by mass of honey produced with the number of turns of given to the wheel (big) sprocket. Knowing the speed ratio (i = 6:3) the number of turns made by the pinion (small) sprocket. This gradient = 6.3 indicates that the speed ratio (i) is constant and the energy used for number for turns for each experiment was uniformly distributed otherwise there will be deviation from originally calculated speed ratio from designed. Small sprocket number turns (t=iT)

Table1: Results of Experiments Conducted

<table>
<thead>
<tr>
<th>Date</th>
<th>Big sprocket's number of Turns (T)</th>
<th>Small sprocket's number of Turns (t = iT)</th>
<th>Mass of honey (kg) collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-7-2010</td>
<td>4</td>
<td>25</td>
<td>1.11</td>
</tr>
<tr>
<td>23-7-2010</td>
<td>6</td>
<td>39</td>
<td>1.74</td>
</tr>
<tr>
<td>29-7-2010</td>
<td>8</td>
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<td>2.23</td>
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<td>63</td>
<td>2.80</td>
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<td>5-8-2010</td>
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<tr>
<td>16-9-2010</td>
<td>36</td>
<td>227</td>
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<tr>
<td>17-9-2010</td>
<td>38</td>
<td>239</td>
<td>9.00</td>
</tr>
</tbody>
</table>

CONCLUSION

The locally required honey extractor of total local content has been designed and fabricated with designed capacity of a litre per minute when spun the basket 202 turns per minute. This gave this extractor relative efficiency of 82%. When compared with imported extractor. The production cost can easily be afforded by the small and medium scale honey product. It required no electricity as source of power so it can be installed in both rural and urban community for optimum use.

RESULT AND DISCUSSION

This study identified the sources of honey, production methods that can be used, its physical characteristics, thermal properties and areas of honey applications which was highly unlimited. This made the need for honey extractor obvious. This extractor was designed, constructed and tested for performance evaluation. The results of the experiment in table 1 shows that as the number of turns increases the quantity by mass of honey extracted increases which shows that as the number of turns increases by spinning the filled basket, the centrifugal force also increases which made the quantity by mass of honey collected to increase between 25 to 202 turns of the basket per minute but the mass of honey collected from the honey combs became constant at 9.0 litres between 202 to 239 turns. This shows that optimum numbers of turns required for optimum mass of honey production is 202 turns going beyond this resulted to energy and time waste. The statistical graph of this experiments is as shown in figure 1.

Comparing the output of the locally fabricated extractor to the imported extractor, the mass of honey collected when fed with same mass of honey comb (15kg) and operated at 202 turns per minute gave 11.00 kg of honey. This made the relative efficiency of the locally fabricated extractor to be 82% (9/11 x 100) = 81.8%

The graph above which at gradient is the found to be

\[
\text{Gradient } i = \frac{(189-63)}{(30-10)} = \frac{126}{20} = 6.3
\]

This gradient = 6.3 indicates that the speed ratio (i) is constant and the energy used for number for turns for each experiment was uniformly distributed otherwise there will be deviation from originally calculated speed ratio from designed. Small sprocket number turns (t=iT)
This graph fig 2 revealed that the quantity by mass of honey increases as its number of turns increases. But at 202 turns to 239 turns. The quantity collected remains at 9.0 litres this indicates the optimum number of turns required to get the 9 litres out of the 15kg of honey combs fed into the basket before spinning. The gradient of the graph when determined. Gradient, \( i = \frac{b_2 - a_2}{b_1 - a_1} = \frac{73.1}{164} = 0.446 \text{kg/turn} \)

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APPENDIX
Figure 2: Orthographic Drawing of the Honey Extractor

Figure 3: Shaft and Chain Drive of the Honey Extractor

Figure 4: Drum Assembly Drawing of the Honey Extractor

Figure 5: Assembly Support of the Honey Extractor

Figure 6: Explosive Drawing of the Honey Extractor