

Development of Pedaled Operated Honey Extractor

Abstract

Bees are winged insects that produce honey by their activities with the nectar of flowers. The honey produced is sweet and are finding replacement for sugar nowadays. Honey bees live in hives where the honey combs being formed by the bees are being deposited. Various methods had been exploited in extracting this honey from the honey comb both traditionally and by different designs of extractors from the primitive to a modern one. Although the former design which was locally produced in Nigeria was hand driven which functions quite efficiently, however, there is need for new innovation that involved the introduction of pedaled mechanism. An existing honey extractor design was improved upon with the introduction of pedal mechanism as compared to the hand driven one with the aim of extracting the honey in the most hygienic way with the suitable materials required. The efficiency of the machine was estimated to be 85 per cent, which was compared to the former available designed one of 83 per cent efficiency. The cost analysis for the production of the machine was included in the work which was estimated to be #48750 (US\$243.75).

Key words: Honey, pedaled, extractor, hive, Bee, improved, shaft, production, machine, efficiency

1.0 INTRODUCTION

Bee is a winged, flower-feeding insect which have branched body hairs. They are dependent on pollen as a protein source and on flower nectar or oils as an energy source. Bees are the most important pollinating insects. Their interdependence with green plant makes them an excellent example of the type of symbiosis known as mutualism; in which two parties of an unlike organisms benefits from each other. Bees produce honey from flower nectar. Honey bees and stingless bees are characterized with the ability to hoard large quantities of honey. This is the major reason for beekeepers to make exploit of this opportunity and harvest the honey for human consumption (Michael, 2008). It is believed that bees are found throughout the world except at the highest altitudes, in Polar Regions, and on some small oceanic islands. This may be due to the fact that the greatest diversity of bee species is found in warm, arid or semi-arid areas especially in the American Southwest and Mexico. Honey bee, the common name for any of several species of highly social bees known for their honey-hoarding behavior and their use as a domesticated species is important in modern agriculture. Honey bees can be easily reared, are adaptable to many climates and to laboratory conditions and have a complex social life. Beekeeping, also known as Apiculture is the management of the colonies of bees for the production of honey and other hive products; and through this practice, different hives had been produced. The early form of collecting honey entailed the destruction of the entire colony when the

honey was harvested. The wild hive was crudely broken into, using smoke to suppress the bees; the honey combs were torn out and smashed up along with the eggs, larvae and honey they contained. The liquid honey from the destroyed brood nest was crudely strained through a sieve or basket. Honey mainly consists of sugars and water. Sugars in honey comprises majorly of monosaccharides and oligosaccharides while sugars in it are sweeter and give more energy than artificial sweeteners. They contain several vitamins especially B complex and vitamin C as well as a lot of minerals (Vallianou *et al.*, 2014). Honey-bee farmers have grown in number to meet the increasing public demand for honey. Honey is a sweet food made by bees using nectar from flowers. Honey has a long history of human consumption and is used in various foods and beverages as a sweetener and flavoring. However, the honey flavors depend on the nectar source.

Honey has numerous health benefits which include the ability to heal wounds, nutritional and therapeutic properties since ancient times. It is good for asthmatic patients and it has been proven to be effective against advanced cases of stomach and bone cancer. Honey is anti-bacteria, anti-viral and anti-fungal; in which all these properties make it ideal for healing wounds (Sampath *et al.*, 2010, Vallianou *et al.*, 2014)

In advanced countries such as United States, Germany, Australia, Italy and so on, series of extractor have been developed and such extractors are tangential, radial, automatic programmable and electrical driven types (Akinnuli *et al.*, 2013). However, the honey extracting machines designed by advanced countries for indigenous beginner in the honey industry are of high cost in which indigenous bee keepers will not be able to purchase the types aforementioned. Afogba (2005) design and constructed the first indigenous honey extractor in the Federal University of Technology, Akure (FUTA), Nigeria; in which the efficiency of the device was 81.8% with the capacity of extracting 9 litres of honey per one cycle. The machine is operated manually using chain and sprocket drive as the prime mover and the materials used for the construction were mild steel, high carbon chromium steel and galvanized steel. Abioye (2006) introduced gear mechanism in transmitting motion that will help in the honey extraction procedure.

In the former designs, large force is required to overcome the load and its metal basket and it takes long time before out flowing of honey from honey combs due to delay in gathering momentum on time. In addition, operator easily get tired after few repetition of the extraction process. Although, the production is appreciable but not good enough when it comes to mass production. In order to overcome these short comings in the hand driven extractor, the system was changed to pedal type, to make the required large force available in spinning the metal basket and its load may gather

momentum within a short period and the honey available get discharged within a very short period. The extracting process can be repeated as many times as possible without the operator being tired. This work was aimed at designing an improved honey extractor that is pedal driven; fabricate the designed improved honey extractor; and evaluate the performance of the produced improved one in comparison with the hand driven type. This will also help the beekeepers to attain better standard of living through improved honey production.

2.0 MATERIALS AND METHODS

The methodology of this research took care of the design analysis of the honey extracting machine, material selection for each component designed, the design calculations of the machine parts, operating description of the system, engineering drawings and required system assembly as well as the estimated production cost.

2.1 Machine Description and Working Principle

The developed extractor was made of axial solid shaft carrying the chain driving system on its accommodations, the small sprocket and the bearing topmost part of the shaft. This solid shaft accommodates the hexagonal shaped basket which will accommodate the matured honey comb ready for extraction. The whole mechanism was housed in a galvanized cylindrical container for honey collection and evacuation. The pedal mechanism which gives the machine a drive (rotary motion) consists of a chain mechanism with a sprocket that transmits the motion from the pedal to the shaft that has a big grooved pulley on it, connected to the shaft that invariably drives the basket inside the drum due to the gear mechanism incorporated. The driver gear set in motion the driven gear which invariably set the basket in motion.

The machine operates by the principle of radial motion of the basket inside the drum. The metal basket was loaded with matured honey combs, and the metal basket was spun to rotation by force on the pedals. The rotational effect caused centrifugal force that made the honey to flow out of its comb. As the centrifugal force increases, the rate of honey outflow increases until the combs are empty of their honey. The extracted honey flows down by gravity into the collector for collection and packaging.

2.2 Design Consideration and Material Selection for Production

Various design considerations were put into place to be able to have efficient design. The tank body or drum, rotary basket, spinning mechanism and shaft were from stainless steel while the frame, gear, chain, bearing and so on were from mild steel. These decisions were taken to avoid rust which can

contaminate the honey and stainless steel used was due to the recommendation for materials preferred for food handling given by Trading Standards agents worldwide.

The materials selected for the design and construction of the machine were majorly the stainless steel and the mild steel. The criteria of selecting these materials are: (i) durability of the material, (ii) strength of the material, (iii) suitability of the material for honey extraction, (iv) availability of the material and (v) the cost of the material.

2.3 Design of Machine Element

a. Straight Bevel Gear Design

These gears have a conical pitch surface and straight tapering towards an apex.

Nomenclature;

Z_p = Number of teeth of pinion

Z_g = Number of teeth on the driven gear

α = Pressure angle of teeth = 20°

ϑ_p = Pitch angle (Pinion) = $\tan^{-1}(Z_p/Z_g)$

n_p = Rotational speed of pinion shaft (rev/min)

d_p = Pinion pitch circle diameter (mm)

d = Driven gear pitch circle diameter (mm)

Gopinath and Maturam [4]

b. Determination of pitch circle diameter

For the pinion P,

$$d_p = mZ_p \quad (1)$$

Where $m = 2.5$ and $Z_p = 21$ teeth

$$d_p = 2.5 \times 21 = 52.5\text{mm} = 0.0525\text{m}$$

For the driven bevel gear,

120 $d_g = mZ_g$ (2)

121 Where $m = 2.5$ and $Z_g = 21$ teeth

122 $d_g = 2.5 \times 21 = 52.5mm = 0.0525m$

123 **c. Determination of pitch angle for bevel gear**

124 The pitch angle is the angle made by the pitch line with the axis of rotation.

125 $\vartheta_p = \tan^{-1}(Z_p/Z_g)$ (3a)

126 $\vartheta_g = \tan^{-1}(Z_g/Z_p)$ (3b)

127 Where $Z_p = 21$ teeth

128 $Z_g = 21$ teeth

129 $\vartheta_p = \tan^{-1}(21/21) = 45^0$

130 $\vartheta_g = \tan^{-1}(21/21) = 45^0$

131 **d. Specification of the selected chain**

132 The selected chain of the type 08B-2 ROLON

133 Pitch, $P = 13\text{ mm}$

134 Maximum Roller Diameter, $D_r = 8\text{ mm}$

135 Width between Inner Plate Minimum, $w = 5\text{ mm}$

136 Pin Body Maximum Diameter, $D_p = 4\text{ mm}$

137 Plate Maximum Depth, $G = 9\text{ mm}$

138 Transverse Pitch, $P_t = 16.5\text{ mm}$

139 Weight per meter = 0.68 kg

140 Minimum Breaking Load, $Q = 1730\text{ kg}$

141 Maximum overall joint, $A_1, A_2, A_3 = 20 \text{ mm}$

142 Number of Teeth of Small Sprocket, $Z_1 = 20$

143 Number of Teeth of Large Sprocket, $Z_2 = 44$

144 **e. Determination of small (pinion) sprockets diameter (mm)**

$$145 \quad d_1 = \frac{P}{\sin \frac{180}{Z_1}} \quad (4a)$$

146 Where P = Pitch of the chain

147 Z_1 = Number of teeth of the small sprocket

148 $d_1 = \text{diameter of small sprocket (pinion)}$ (Maleev and James) [7]

$$149 \quad d_1 = \frac{13}{\sin \frac{180}{20}} = \frac{13}{\sin 9} = 83.11 \text{ mm}$$

150 **f. Determination of large sprocket diameter**

$$151 \quad d_2 = \frac{P}{\sin \frac{180}{Z_2}} \quad (4b)$$

152 Where P = Pitch of the chain

153 Z_2 = Number of teeth of the large sprocket

154 $d_2 = \text{diameter of large sprocket}$

$$155 \quad d_2 = \frac{13}{\sin \frac{180}{44}} = \frac{13}{\sin 4.091} = 182.23 \text{ mm}$$

156 **g. Determination of the service factor, K_s**

157 The service factor, also referred to as selection factor, takes into consideration the condition under which
158 the chain drive will be working.

$$159 \quad K_s = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \quad (5)$$

160 Where:

161 Local Factor, $k_1 = 1.0$

162 The factor distance regulation, $k_2 = 1.25$

163 Factor for centre distance of sprocket, $k_3 = 1.25$

164 Factor for portion of the sprocket, $k_4 = 1.0$

165 The lubrication factor, $k_5 = 1.5$

166 The rating factor, $k_6 = 1.0$

167 $K_s = 1.0 \times 1.25 \times 1.25 \times 1.0 \times 1.5 \times 1.0$

168 $= 2.34375$

169 **h. Determination of the speed of the pinion**

170 $\frac{Z_2}{Z_1} = \frac{n_1}{n_2}$ (6)

171 Where n_2 = speed of the driver sprocket.

172 n_1 = speed of the pinion

173 $n_1 = \frac{Z_2 n_2}{Z_1} = \frac{44 \times 60}{20} = 132 \text{ rpm}$

174 **i. Determination of the factor of safety**

175 The factor of safety η , is given by

176 $\eta = \frac{Q}{P}$ (7)

177 where $P = P_t + P_c + P_s$ (8)

178 P_t = tangential force due to power transmission

179 P_c = centrifugal force

180 P_s = tension due to sagging of chain

181 Where $P_s = K_s \cdot W \cdot a$ (9)

182 Where K_s = coefficient of sag = 6

183 $a = \text{centre distance} = 0.39 \text{ m}$

184 $W = \text{weight per metre of chain} = 0.77 \text{ kgF}$

185 Therefore, $P_s = 6 \times 0.77 \times 0.39 = 1.8018 \text{ kgF}$. (Sharma and Purohit, 2003) [8]

186 **j. The centrifugal tension, P_c**

187 $P_c = WV^2/g$ (10)

188 Where $g = \text{acceleration due to gravitational pull} = 9.81 \text{ m/s}^2$

189 $V = \text{chain velocity (m/s)} = \frac{d_1 n_1}{60}$ (11)

190 $V = \frac{0.08311 \times 132}{60} = 0.5746 \text{ m/s}$.

191 $P_c = \frac{0.77 \times 0.5746^2}{9.81} = 0.0259 \text{ kgF}$

192 The tangential force due to power transmission P_t

193 $P_t = \frac{102N}{V}$

194 Where $N = \text{power transmitted on the basis of breaking load}$

195 $N = \frac{QV}{102nK_s}$ (12)

196 Where $Q = \text{breaking load} = 1730 \text{ kgF}$

197 $d_1 = \text{diameter of small sprocket} = 0.83109 \text{ m}$

198 $V = \text{chain velocity (m/s)} = 0.5746 \text{ m/s}$

199 $n = \text{factor of safety} = 7.8$

200 $K_s = \text{service factor} = 2.34375$

201 $N = \frac{1730 \times 0.5746}{102 \times 7.8 \times 2.34375} = 0.5331 \text{ kW}$

202 Hence, $P_t = \frac{102 \times 0.5331}{0.5146} = 105.667 \text{ kgF}$

$$203 \quad P = P_t + P_c + P_s = 1.8018 + 0.0259 + 105.667 = 107.4947 \text{ kgF}$$

$$204 \quad P = 107.4947 \times 9.81 = 1054.52 \text{ N}$$

205 Hence the actual factor of safety (η)

$$206 \quad \eta = \frac{Q}{P} = \frac{1730}{1054.52} = 1.64$$

207 **k. Determination of the required torque to rotate the Load-Carrying shaft**

208 Safe speed of the rotating basket to ensure 90% efficiency and to preserve the comb from damaging is
209 between 180 to 320 rpm

210 Therefore, the required selected speed of shaft, $V_s = 250 \text{ rpm}$

211 Mass of shaft (without load), $m_s = 1.8 \text{ kg}$

212 Mass of basket (without load), $m_{bk} = 6.2 \text{ kg}$

213 Mass of bearing, $m_b = 0.2 \text{ kg}$

214 Mass of one (1) honey comb + frame, $m_h = 1.1 \text{ kg}$

215 Mass of one (6) honey comb + frame = 6.6 kg

216 Mass of shaft (with load), $m = m_s + m_{bk} + m_b + m_h$

$$217 \quad m = 1.8 + 6.2 + 0.2 + 6.6 = 14.8 \text{ kg}$$

218 To calculate the torque of the rotating basket

$$219 \quad T = I\alpha \quad (13)$$

220 Where T = Torque of the basket

221 I = moment of inertia of the basket

222 α = angular acceleration of the basket

223 To determine the moment of inertia of the basket, $I = \frac{1}{2}mr^2$ (14)

224 Where m = mass of loaded shaft = 14.8 kg

225 r = radius of the basket from the centre = 0.33m

226 $I = \frac{1}{2} \times 14.8 \times (0.33)^2 = 0.8059 \text{ kg/m}^2$

227 To determine α ,

228 Angular velocity of the basket, $\omega = \frac{2\pi V}{60} = \frac{2\pi \times 250}{60} = 26.19 \text{ rad/s}$

229 $\alpha = \omega^2 r = 26.19^2 \times 0.33 = 226.35 \text{ rad/s}^2$

230 Hence the torque $T = 0.8059 \times 226.35 = 182.42 \text{ Nm}$

231 **I. Determination of the required power to drive the rotary basket**

232 $P = \frac{2\pi TV}{60}$ (15)

233 Where P = Power

234 T = Torque = 182.42 Nm

235 V = Speed in rpm = 250 rpm

236 $P = \frac{2\pi \times 182.42 \times 250}{60} = 4777.99 \text{ Watts}$

237 $P = 4.78 \text{ kW}$ (Tyler, 2006) [11]

238 To determine the V-belt design power, P'

239 $P' = SF \times P$ (16)

240 SF = Service factor = 1.1 (for centrifugal machine performing intermittent service)

241 P = Required power = 4.78 kW

242 $P' = 1.1 \times 4.78 = 5.26 \text{ kW}$

243 The following known parameters were used in the determination of the speed ratio

244 Design Power, $P = 5.26 \text{ kW}$

245 Driven pulley rotational speed, $n_{p2} = 250 \text{ rpm}$

246 Driver pulley rotational speed, $n_{p1} = 132 \text{ rpm}$

247 Distance between axes of pulley, $A = 480 \text{ (pre – selected)}$

248 Acceptance error for belt drive ratio, $\Delta = 3\%$

249 **m. Limitation of the belt drive ratio, i**

250
$$i = \frac{n_{p2}}{n_{p1}} \quad (17)$$

251
$$= \frac{250}{132} = 1.89$$

252
$$i_{\max} = i \times \left[1 + \frac{\Delta}{2.1} \right] \quad (18a)$$

253
$$i_{\max} = 1.89 \times \left[1 + \frac{0.03}{2.1} \right] = 1.917$$

254
$$i_{\min} = i \times \left[1 - \frac{\Delta}{2.1} \right] \quad (18b)$$

255
$$i_{\min} = i \times \left[1 - \frac{0.03}{2.1} \right] = 1.863$$

256 The diameter chosen for the driver pulley, $D_1 = 125 \text{ mm}$

257 The diameter chosen for the driven pulley, $D_2 = 250 \text{ mm}$

258 The real drive ratio, $i_{\text{real}} = \frac{D_2}{D_1} \quad (19)$

259
$$= \frac{250}{125} = 2$$

260 The belt drive ratio $i_{\text{real}} = 2$ is acceptable (Shigley and Mischke) [9]

261 **n. Selection of a length of the belt**

262 Angle of slope, γ of the belt is calculated as

$$263 \quad \sin \gamma = \frac{D_2 - D_1}{2A} \quad (20)$$

$$264 \quad = \frac{250 - 125}{2(480)} = 0.1302$$

$$265 \quad \gamma = \sin^{-1}(0.1302) = 7.48^\circ$$

266 **o. Length of the belt**

$$267 \quad L = \pi \left[\frac{D_1 + D_2}{2} \right] + \pi \left[\frac{\gamma}{180} \right] [D_2 - D_1] + 2A \cos \gamma \quad (21)$$

$$268 \quad L = 3.143 \left[\frac{125 + 250}{2} \right] + 3.143 \left[\frac{7.48}{180} \right] [250 - 125] + 2[480 \cos 7.48] = 1557 \text{ mm}$$

269 Therefore, a length $L=1600\text{mm}$ was chosen (Spotts, 1991) [10]

270 In calculating the belt speed V (m/s)

$$271 \quad V = \frac{D_1 n_1}{60 \times 10^3}$$

$$272 \quad V = \frac{125 \times 132}{60 \times 10^3} = 0.8639 \text{ m/s}$$

273 **p. Determination of the force required to drive the shaft and basket**

274 The calories required for riding a bicycle is 175 cal/hr (Thorge *et al.*, 1970)

275 Therefore if 1 cal = 4.184 J

$$276 \quad 175 \text{ cal} = (175 \times 4.184) \text{ J}$$

$$277 \quad 175 \text{ cal} = 732.2 \text{ J/hr}$$

$$278 \quad \text{But Power} = \frac{\text{work}}{\text{time}} (\text{J/sec}) \quad (22)$$

$$279 \quad \text{Power} = \frac{732.2}{3600} \text{ J/sec} = 0.2034 \text{ J/sec}$$

$$280 \quad \text{Also Power}(P) = \text{Force}(F) \times \text{Velocity}(V)$$

281 $P = F \times V$ (23)

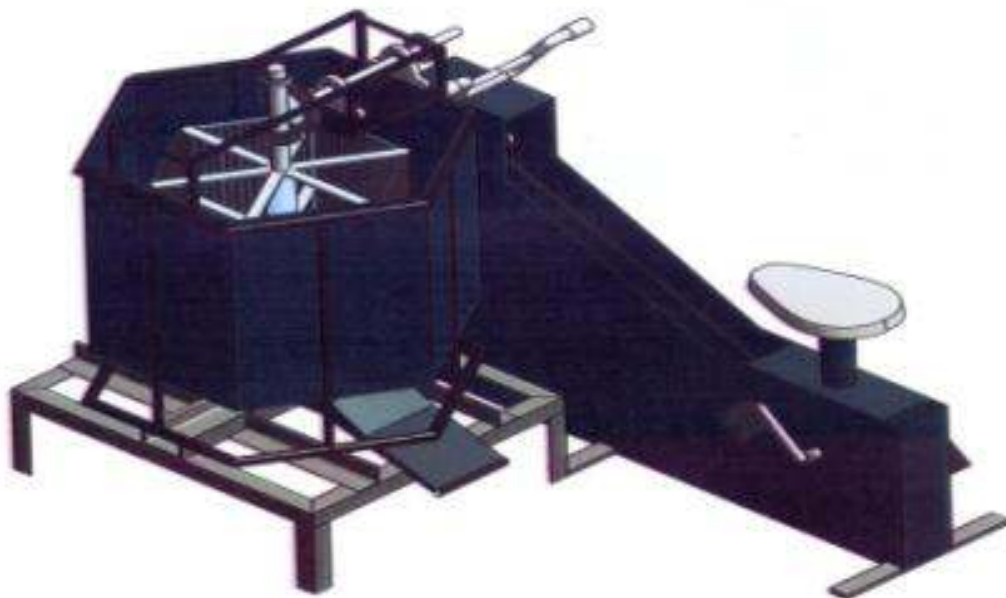
282 $F = \frac{P}{V}$

283 $F = \frac{0.2034}{0.577} = 0.3525 \text{ N}$

284 All the formulas used for the analysis were from [4] – [11]

285 **r. Engineering Drawings for Production**

286 The isometric drawing of this machine is as shown in Fig.1. The orthographic views as well as the exploded
287 drawing and other drawings of the component parts are as shown in Figs. 2, 3,4,5,6 and 7.



288

289 Figure 1: Isometric view of the honey extractor

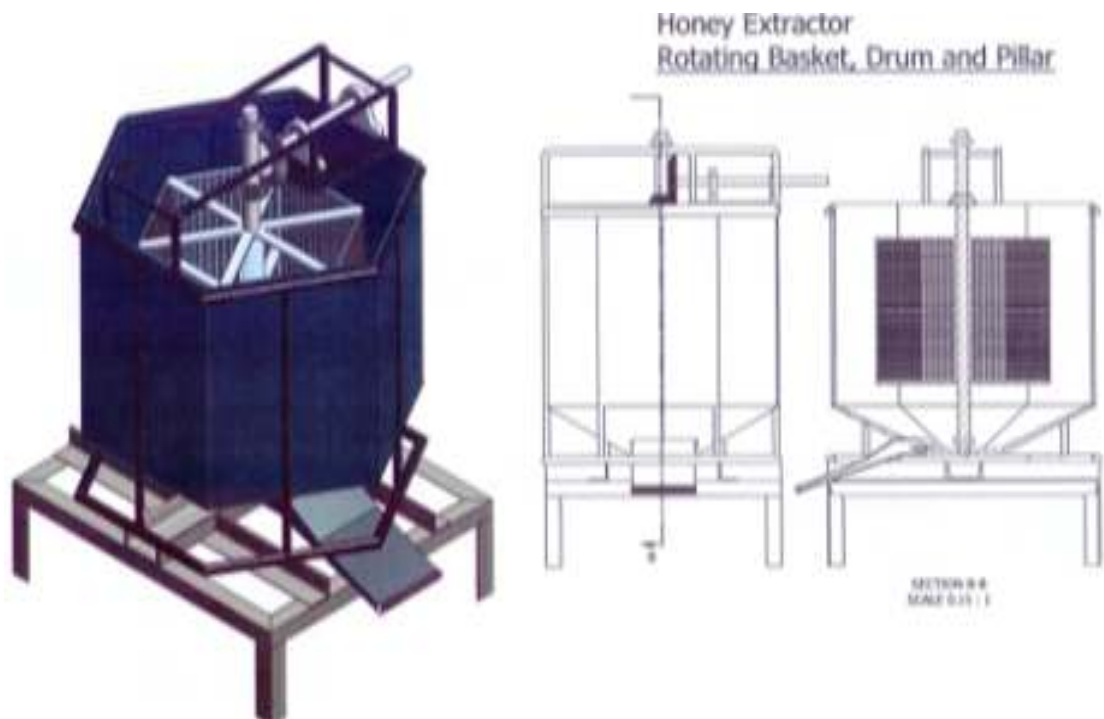


Figure 2: Conceptual and frame diagrams for the honey extractor drum with basket

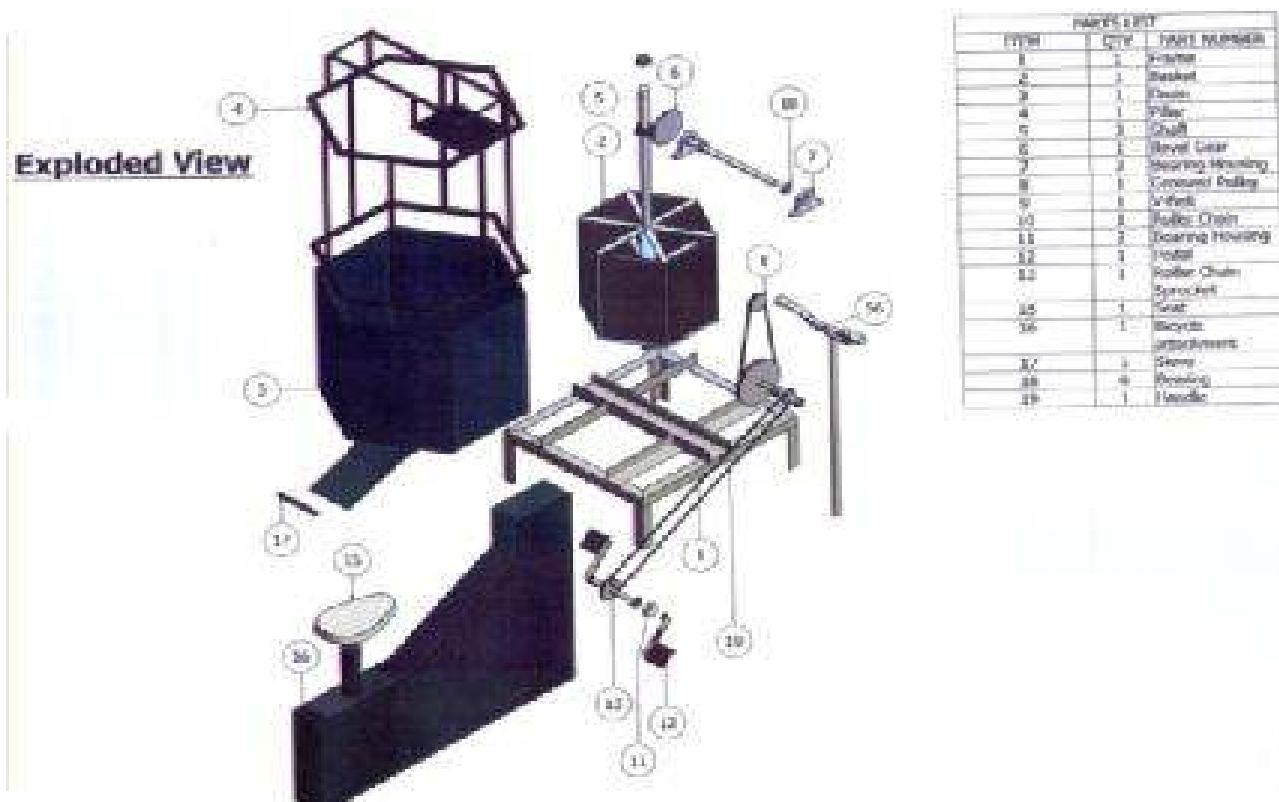
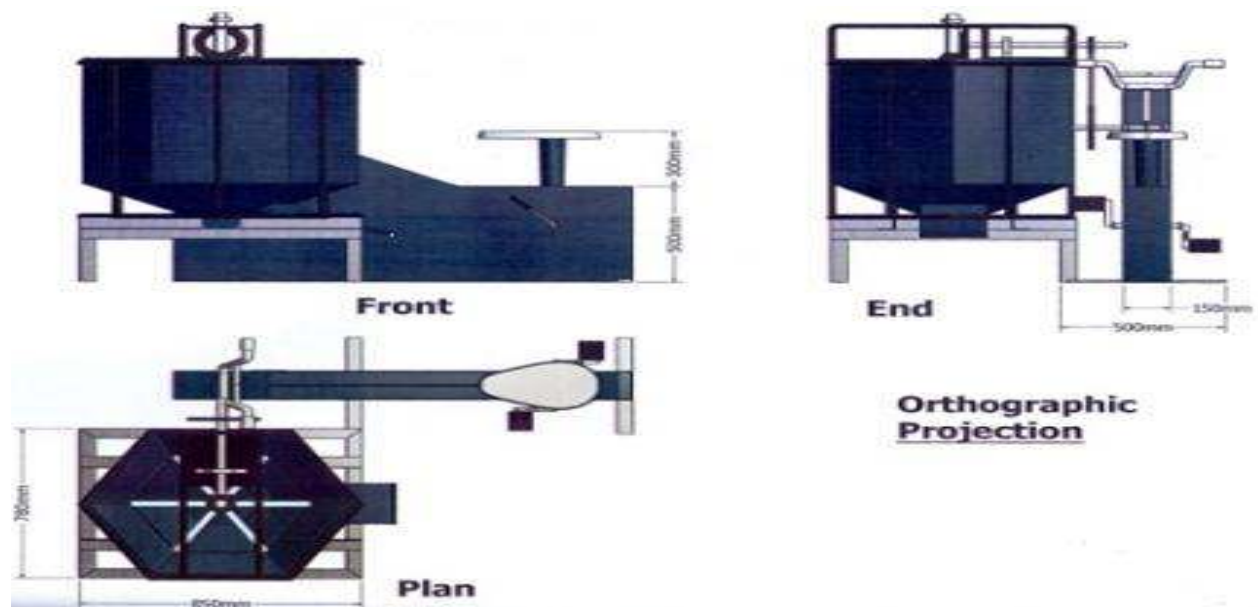


Figure 3: Exploded view of the honey extractor

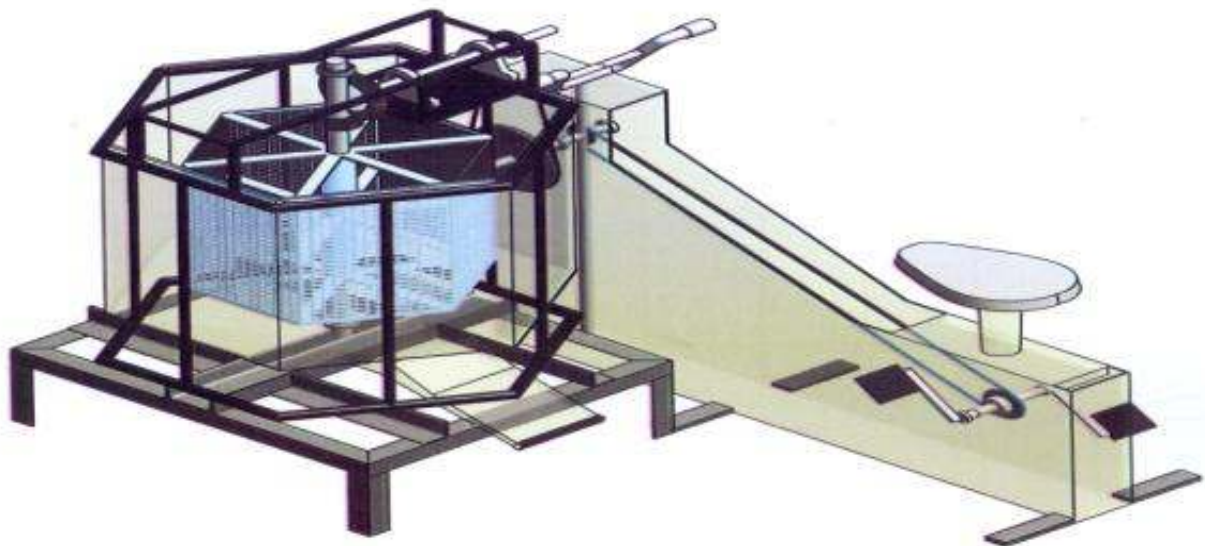
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296

297 Figure 4: Orthographic projection of the honey extractor

298



299

300 Figure 5: Isometric conceptual diagram for the honey extractor

301 2.5 Production Cost

302 The table below shows the cost estimates involved in the production of the honey extractor.

303

304

Table 1: Production Cost

		#	USD\$
i.	Bought-out component cost	10150	50.75
ii.	Material cost	27000	135
iii.	Machining cost	6100	30.5
iv.	Non-machining cost	5500	27.5
Total Estimated cost		48750	243.75

2.6 Performance Evaluation of the Machine

The design of the honey extracting machine was targeted towards obtaining 250 rpm speed of the revolving honey frame (rotary basket). At the end of the construction, the maximum speed attainable was 270 rpm. During the test of the efficiency of the machines, these were the results gathered. However, it is important to note that the frame rotary basket was reloaded with new honey combs at each working operation.

Table 2: Performance Evaluation for the Machine

S/No	Parameter	First working condition	Second Working condition	Third working condition	Average
1	Density of honey (kg/m ³)	1402.7	1402.7	1402.7	1402.7
2	Total mass of honey frame (kg)	6.6	6.6	6.6	6.6
3	Speed of the frame basket (rpm)	250	260	270	260
4	Time taken for operation (min)	20	20	15	18.3
5	Volume of honey extracted (m ³)	0.004	0.004	0.004	0.004
6	Mass of honey extracted (kg)	5.61	5.61	5.61	5.61

Since efficiency is known to be the ratio of output to input, the formula for the production efficiency was derived and efficiency (ε) by calculation was

$$\varepsilon = \frac{\text{mass of extracted honey}}{\text{mass of honey comb processed}} \times 100\%$$
$$= \frac{5.61}{6.60} \times 100\% = 85\%$$

3.0 RESULTS AND DISCUSSION

Table 2 shows the average volume of the honey, average mass of honey, average speed of the rotating basket, average time taken for the operation to be 0.004 m³, 5.61 kg, 260 rpm and 18.3 min respectively.

When average mass of 6.6kg honey comb was fed into the spinning metal basket, the hand driven type averagely produced 5.50 kg of honey while the pedal type produced 5.61 kg of honey. Hence, the production efficiency of this design was 85% as compared to the design of Afogba (2005) and Abioye (2006). The efficiency of their designs were 81.8% and 83.29% respectively. This is a slight improvement to existing designs. Although, the previous design was an extractor locally made for indigenous honey keepers which was hand driven was effective to some extent; however; in terms of production en mass, the hand driven extractor is not very effective because it can cause occupational health disorder to its user due to repetitive cycling of the hand driver of the extractor. The pedal driven extractor uses a mechanism that helps gather easy momentum to drive the extractor within a short period unlike the hand driven type; hence reducing occupational health disorder encountered in the former design. The modification made on the machine was the changing of the hand driven mechanism to the pedal driven mechanism. From the table 1, the production cost for the entire machine was estimated to be #48750 (\$243.75).

3.0 CONCLUSION

Hand driven honey extractor formerly designed was redesigned so that it could accommodate a pedal mechanism instead of being driven by hand. It was an improved design on the former design because the effectiveness of the former design was 83.29% and that of this new design was 85%; in which the new one was found to be more efficient. Also the shortcomings as observed in the previous design were overcome in this new design in that the operator that easily get tired after a few repetition in driving the extractor can now spin repeatedly as many times as possible without being tired. This is an increase to productivity of the system and can be employed in mass production of honey. The honey extractor is an effective and hygienic means of extracting honey from the honey comb. Although the design might be quite expensive, it met the desired requirement of hygienic food handling and it is

352 maintenance friendly, in that all the parts are replaceable when the need arises. The users of this
353 machine will find it interesting to operate. It can be operated by anyone who has the little energy
354 required to drive the pedals.

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