

Original Research Articles

Development of Pedaled 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. This work is aimed at improving on the design of the existing honey extractor designed and fabricated by Akinnuli et al. (2013) with the introduction of the pedal mechanism to the honey extractor using the well needed materials for the production of the machine following the required standards for food processing. The efficiency of the machine was obtained to be 85 per cent, which was compared to the former available designed one of 82% efficiency. The cost analysis for the production of the machine was included in the work. It is hoped that the machine will serve as a means of exercise for the farmers and will help to extract the honey in a hygienic and efficient manner.

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. Bees are found throughout the world except at the highest altitudes, in Polar Regions, and on some small oceanic islands. The greatest diversity of bee species is found in warm, arid or semi-arid areas especially in the American Southwest and Mexico. Keneth (2007) in his work classified honey bees. 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. However, the management of colonies of bees for the production of honey and other hive products and for the pollination of crops is called Beekeeping also referred to as Apiculture. Different hives had been established. 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 has become a generally accepted substitute for sugar worldwide; therefore 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.

John (2007) revealed in his work that small-scale honey extractors have not changed much during the past 100 years. Major Hruschka, an Austrian, in 1865 invented a centrifugal honey extractor and in 1895, a radial honey extractor design was done by Bohn which was probably developed from an earlier design of radial extractor which was time saving unlike the previous design. In 1913, heat was being applied in separating honey from wax. It was a thin partition which is a concept of drawing off honey from the bottom of a container and wax from the top and it is still in used till today. The wagon extracting is still in used today too. However, it is normally used at night when the bees' robbing would not be a problem. Extractors are either tangential or radial depending on how the frames are put into the basket. Radial baskets have the top bar of the frame facing outwards while tangential baskets have one side of the comb facing outward. Large commercial extractors are radial and rely on the upward slope of the comb cells. This slope allows extracting honey by applying centrifugal force toward the upper edge of the comb (opposite to the direction of gravity while in the hive). The amount of work during extraction is reduced in the radial type because the frames do not have to be turned over to extract the honey from the other side of the comb. However, some extractors are capable of turning combs automatically. Hobbyist extractors can be manually driven or electric motor powered. If the extractor is manually driven, it often has accelerating gear to spin with less effort. During the extraction process, the honey is forced out of the uncapped wax cells, runs down the walls of the extractor and pools at the bottom. A tap or honey pump allows for the removal of honey from the extractor. Honey must be removed in time and always stay below the rotating frames else it will prevent extractor from spinning with sufficient speed. In 2005, a design of this machine was done and constructed in the Federal University of Technology, Akure, Nigeria (FUTA); in which the efficiency of the device was 81.8% with the capacity of extracting 9 litres of honey per one cycle (Afogba, 2005). 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. However, a modification was done on the work of Afogba (2005) by Abioye in 2006. He opined that

gear drives have advantages over other drives when transmitting of motion or power between two shafts. The modified design was driven manually by gear connections which operate at a speed of 120 revolutions per minute (rpm) and with the capability of extracting 15 litres of honey per one working operation to a production efficiency of 81.29%.

Additionally, honey extractors also come in variety of sizes. Larger extractors are basically intended for commercial uses while the smaller ones are ideal for small scale businesses. Regardless of which type of honey extractor chosen, purpose must be suited as well as cost effective for targeted farmers.

This work was aimed at designing, producing and testing a radial type honey extractor which is a modification to the existing designs. This work will help to reduce effort required in spinning the mechanism by introducing peddling mechanism and which might also serve as a means of exercise for the farmer peddling the machine. This will also help the beekeepers to attain better standard of living through improved honey production. It will also help to establish the introduction of leg peddling mechanism as an efficient method of reducing the effort required to spin a rotary component.

2.0 MATERIALS AND METHODOLOGY

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 Design Consideration and Material Selection for Production

Various design considerations were put into place to be able to have efficient design. These include the design considerations for tank body or drum, drives, rotary basket, spinning mechanism, structural frame, shaft, bearing, gear and chain drive.

2.1.1 Material Selection

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. However, due to the recommendation by Trading Standards agents worldwide which includes NAFDAC, in which plastic, tin plate and stainless steel were the materials preferred for food handling. Therefore, stainless steel was selected for the parts that the honey will be in contact with. Stainless steel is preferred so as to prevent poisonous corrosive

substance. Mild steel was also selected for the parts that will not be in contact with the honey being extracted due to their good machining and weld-ability properties and high strength. The material selection is summarized in the Table 1 as well as the reasons for their selection

Table 1: Proposed material for components production before assembly

S/No	Machine parts	Material selection	Reason for selection
1.	Drum	Stainless steel	Good corrosion resistance, non-poisonous and Strength, non-reacting with food.
2.	Rotary basket	Stainless steel	Good corrosion resistance, non-poisonous and Strength, non-reacting with food.
3.	Frame	Mild Steel	Good weldability, high strength and durability.
4.	Shaft	Stainless steel	Good corrosion resistance, non-poisonous and Strength, non-reacting with food.
5.	Bearing	High Carbon Chromium steel	High strength, availability, Aligning properties.
6.	Gear	Mild Steel	Good machining and wearing properties, strength and availability.
7.	Chain	Heat-treated Mild steel	Good machining and wearing properties and availability.
8.	Handle	Mild steel	Formability, strength and low cost.

2.2 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

121 Z_g = Number of teeth on the driven gear

122 α = Pressure angle of teeth = 20^0

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

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

125 d_p = Pinion pitch circle diameter (mm)

126 d = Driven gear pitch circle diameter (mm)

Gopinath and Maturam [4]

127 **2.3 Determination of pitch circle diameter**

128 For the pinion P,

$$129 \quad d_p = mZ_p \quad (1)$$

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

$$131 \quad d_p = 2.5 \times 21 = 52.5mm = 0.0525m$$

132 For the driven bevel gear,

$$133 \quad d_g = mZ_g \quad (2)$$

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

$$135 \quad d_p = 2.5 \times 21 = 52.5mm = 0.0525m$$

136

137 **2.4 Determination of pitch angle for bevel gear**

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

$$139 \quad \vartheta_p = \tan^{-1}(Z_p/Z_g) \quad (3a)$$

$$140 \quad \vartheta_g = \tan^{-1}(Z_g/Z_p) \quad (3b)$$

141 Where $Z_p = 21$ teeth

$$Z_g = 21 \text{ teeth}$$

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

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

2.5 Specification of the selected chain

The selected chain of the type 08B-2 ROLON

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

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

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

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

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

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

Weight per meter = 0.68 kg

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

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

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

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

158

2.6 Determination of the Sprockets Diameters

2.6.1 Determination of small (pinion) sprockets diameter (mm)

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

Where $P = \text{Pitch of the chain}$

163 Z_1 = Number of teeth of the small sprocket

164 $d_1 = \text{diameter of small sprocket (pinion)}$ (Maleev and James) [7]

165
$$d_1 = \frac{13}{\sin \frac{180}{20}} = \frac{13}{\sin 9} = 83.11 \text{ mm}$$

166 2.6.2 Determination of large sprocket diameter

167
$$d_2 = \frac{P}{\sin \frac{180}{Z_2}} \quad (4b)$$

168 Where P = Pitch of the chain

169 Z_2 = Number of teeth of the large sprocket

170 $d_2 = \text{diameter of large sprocket}$

171
$$d_2 = \frac{13}{\sin \frac{180}{44}} = \frac{13}{\sin 4.091} = 182.23 \text{ mm}$$

172 2.7 Determination of the service factor, K_s

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

175
$$K_s = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \quad (5)$$

176 Where:

177 Local Factor, $k_1 = 1.0$

178 The factor distance regulation, $k_2 = 1.25$

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

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

181 The lubrication factor, $k_5 = 1.5$

182 The rating factor, $k_6 = 1.0$

183
$$K_s = 1.0 \times 1.25 \times 1.25 \times 1.0 \times 1.5 \times 1.0$$

184 $= 2.34375$

185 **2.8 Determination of the speed of the pinion**

186
$$\frac{Z_2}{Z_1} = \frac{n_1}{n_2} \quad (6)$$

187 Where n_2 = speed of the driver sprocket.

188 n_1 = speed of the pinion

189
$$n_1 = \frac{Z_2 n_2}{Z_1} = \frac{44 \times 60}{20} = 132 \text{ rpm}$$

190 **2.9 Determination of the factor of safety**

191 The factor of safety η , is given by

192
$$\eta = \frac{Q}{P} \quad (7)$$

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

194 P_t = tangential force due to power transmission

195 P_c = centrifugal force

196 P_s = tension due to sagging of chain

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

198 Where K_s = coefficient of sag = 6

199 a = centre distance = 0.39 m

200 W = weight per metre of chain = 0.77 kgF

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

202 **2.10 The centrifugal tension, P_c**

203
$$P_c = WV^2/g \quad (10)$$

204 Where g = acceleration due to gravitational pull = 9.81 m/s²

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

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

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

The tangential force due to power transmission P_t

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

Where N = power transmitted on the basis of breaking load

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

Where Q = breaking load = 1730 kgF

d_1 = diameter of small sprocket = 0.83109 m

V = chain velocity (m/s) = 0.5746 m/s

n = factor of safety = 7.8

K_s = service factor = 2.34375

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

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

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

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

Hence the actual factor of safety (η)

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

2.11 Determination of the required torque to rotate the Load-Carrying shaft

224 Safe speed of the rotating basket to ensure 90% efficiency and to preserve the comb from damaging is
225 between 180 to 320 rpm (Mike Miles, -----year).

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

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

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

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

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

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

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

233 $m = 1.8 + 6.2 + 0.2 + 6.6 = 14.8 \text{ kg}$

234 To calculate the torque of the rotating basket

235 $T = I\alpha$ (13)

236 Where T = Torque of the basket

237 I = moment of inertia of the basket

238 α = angular acceleration of the basket

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

240 Where m = mass of loaded shaft = 14.8 kg

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

242 $I = \frac{1}{2} \times 14.8 \times (0.33)^2 = 0.8059 \text{ kg/m}^2$

243 To determine α ,

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

245 $\alpha = \omega^2 r = 26.19^2 \times 0.33 = 226.35 \text{ rad/s}^2$

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

247 **2.12 Determination of the required power to drive the rotary basket**

248 $P = \frac{2\pi TV}{60}$ (15)

249 Where P = Power

250 T = Torque = 182.42 Nm

251 V = Speed in rpm = 250 rpm

252 $P = \frac{2\pi \times 182.42 \times 250}{60} = 4777.99 \text{ Watts}$

253 $P = 4.78 \text{ kW}$ (Tyler, 2006) [11]

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

255 $P' = SF \times P$ (16)

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

257 P = Required power = 4.78 kW

258 $P' = 1.1 \times 4.78 = 5.26 \text{ kW}$

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

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

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

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

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

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

265 **2.13 Limitation of the belt drive ratio, i**

$$266 \quad i = \frac{n_{p2}}{n_{p1}} \quad (17)$$

$$267 \quad = \frac{250}{132} = 1.89$$

$$268 \quad i_{\max} = i \times \left[1 + \frac{\Delta}{2.1} \right] \quad (18a)$$

$$269 \quad i_{\max} = 1.89 \times \left[1 + \frac{0.03}{2.1} \right] = 1.917$$

$$270 \quad i_{\min} = i \times \left[1 - \frac{\Delta}{2.1} \right] \quad (18b)$$

$$271 \quad i_{\min} = i \times \left[1 - \frac{0.03}{2.1} \right] = 1.863$$

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

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

$$274 \quad \text{The real drive ratio, } i_{\text{real}} = \frac{D_2}{D_1} \quad (19)$$

$$275 \quad = \frac{250}{125} = 2$$

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

277 **2.14 Selection of a length of the belt**

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

$$279 \quad \sin \gamma = \frac{D_2 - D_1}{2A} \quad (20)$$

$$280 \quad = \frac{250 - 125}{2(480)} = 0.1302$$

$$281 \quad \gamma = \sin^{-1}(0.1302) = 7.48^\circ$$

282 **2.15 Length of the belt**

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

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

Therefore, a length L=1600mm was chosen (Spotts, 1991) [10]

In calculating the belt speed V (m/s)

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

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

2.16 Determination of the force required to drive the shaft and basket

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

Therefore if 1 cal = 4.184 J

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

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

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

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

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

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

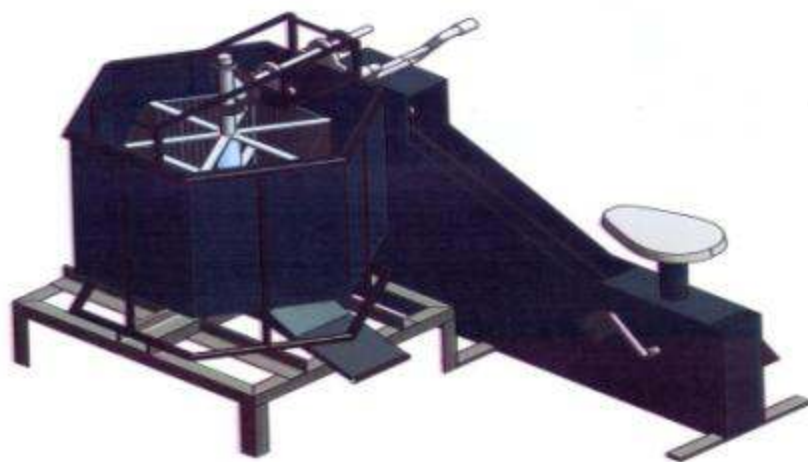
$$F = \frac{P}{V}$$

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

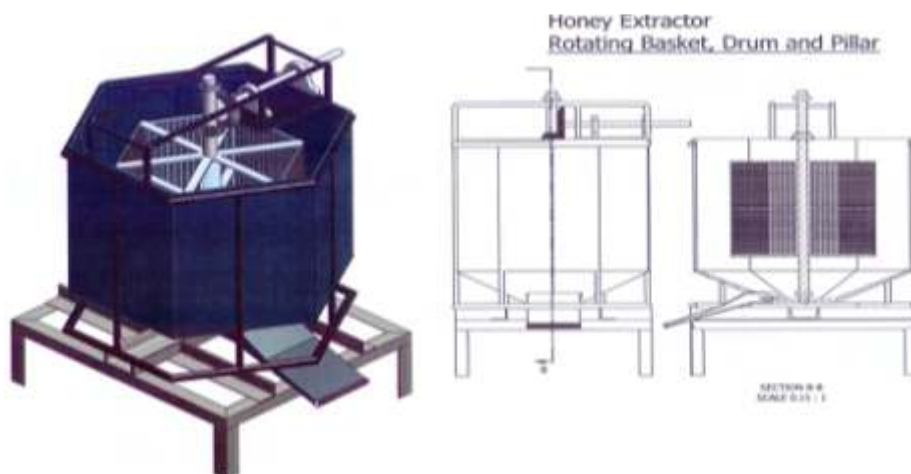
All the formulas used for the analysis were from [4] – [11]

2.17 Engineering Drawings for Production

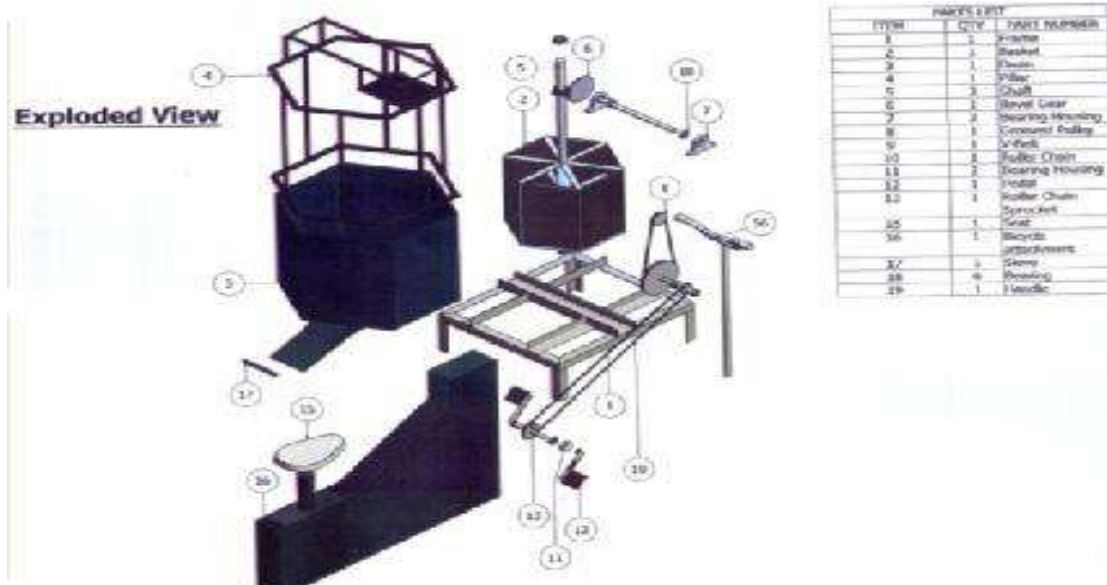
302 The isometric drawing of this machine is as shown in Fig.1. The orthographic views as well as the exploded
303 drawing and other drawings of the component parts are as shown in Figs. 2, 3,4,5,6 and 7.



304
305 Figure 1: Isometric view of the honey extractor

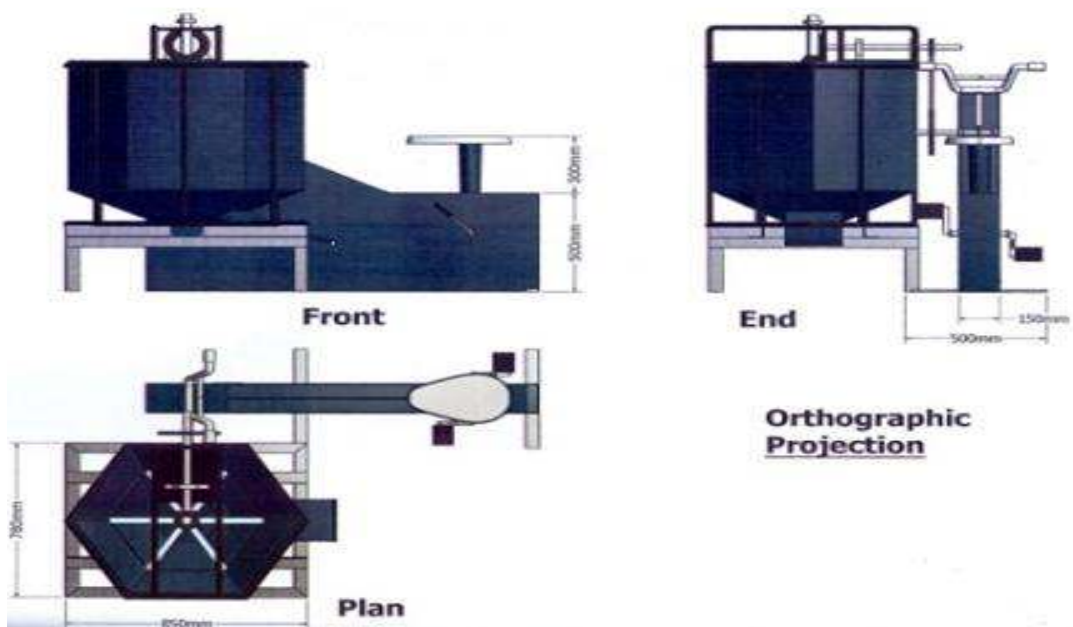


306
307 Figure 2: Conceptual and frame diagrams for the honey extractor drum with basket



308

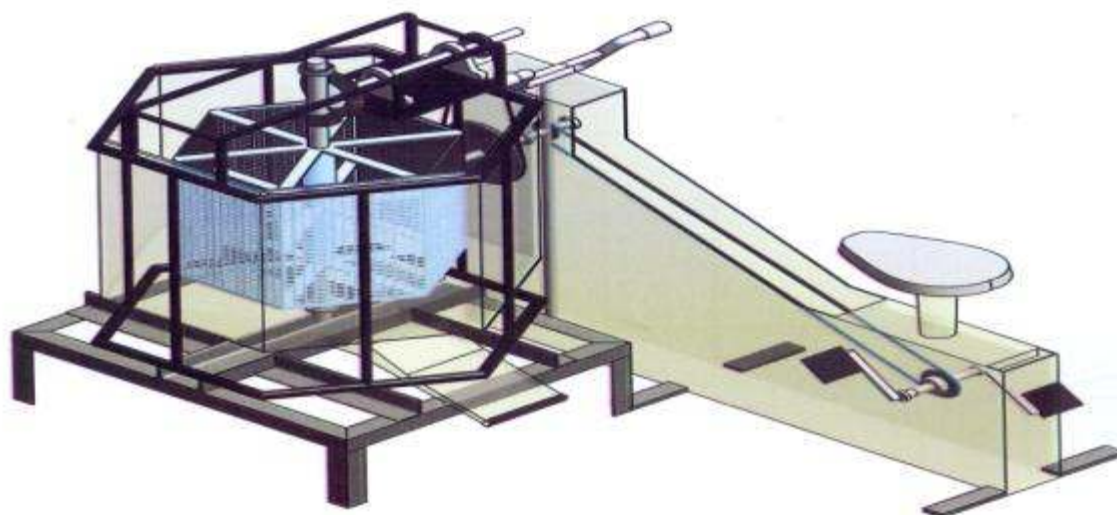
309 Figure 3: Exploded view of the honey extractor



310

311 Figure 4: Orthographic projection of the honey extractor

312



313

314 Figure 5: Isometric conceptual diagram for the honey extractor

315 2.18 Production Cost

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

317 **Table 2: Production Cost**

		#	USD\$
319	i. Bought-out component cost	10150	50.75
320	ii. Material cost	27000	135
321	iii. Machining cost	6100	30.5
322	iv. Non-machining cost	5500	27.5
323	Total Estimated cost	49100	243.75

324

325 3.0 RESULTS AND DISCUSSION

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

331 First working condition

332 Density of honey = 1402.7 kg/m^3

333 Total mass of honey frame= 6.6 kg

334 Speed of frame basket= 250 *rpm*

335 Time taken for operation= 20 *min*

336 Volume of honey extracted= $0.004m^3$ (4 litres)

337 Mass of honey extracted= *Volume* $\times$ *Density*

338 = $0.004 \times 1402.7 = 5.61kg$

339 **Second working condition**

340 Density of honey = $1402.7 \text{ kg}/m^3$

341 Total mass of honey frame= 6.6 *kg*

342 Speed of frame basket= 260 *rpm*

343 Time taken for operation= 20 *min*

344 Volume of honey extracted= $0.004m^3$ (4 litres)

345 Mass of honey extracted= *Volume* $\times$ *Density*

346 = $0.004 \times 1402.7 = 5.61kg$

347 **Third working condition**

348 Density of honey = $1402.7 \text{ kg}/m^3$

349 Total mass of honey frame= 6.6 *kg*

350 Speed of frame basket= 270 *rpm*

351 Time taken for operation= 15 *min*

352 Volume of honey extracted= $0.004m^3$ (4 litres)

353 Mass of honey extracted= *Volume* $\times$ *Density*

354 = $0.004 \times 1402.7 = 5.61kg$

355 Therefore, for a mass of 6.6 kg of honey at an average speed of 260 rpm with an average operation
356 time of 18.33 min, the average mass of the honey extracted, $m = 5.61kg$.

357 The production efficiency by calculation was

$$358 \quad \varepsilon = \frac{\text{mass of extracted honey}}{\text{mass of honey comb processed}} \times 100\%$$

$$359 \quad = \frac{5.61}{6.60} \times 100\% = 85\%$$

360 Hence, the production efficiency of this design was 85% as compared to the design of Afogba (2005)
361 and Abioye (2006) where the efficiency of their designs were 81.8% and 83.29% respectively. This is
362 indeed an improved development to the existing designs.

363

364

4.0 CONCLUSION

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

This user friendly machine is recommended for improvement in that in reducing the total cost of production for the rural farmers, alternative materials like plastic or rubber can be used for the drum part of the machine.

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