QUEST TOWARDS ESTABLISHING THE TECHNICAL SPECIFICATIONS FOR INDIGENOUS OIL PALM BIOMASS PROCESSING MACHINERY

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Abstract: Prompted by their abundant availability throughout Malaysia, oil palm fibres is a very much sought after material for a wide range of downstream applications. This development coupled with inefficiencies of the conventional wood processing machines has led to the need of a reliable processing machine to extract lignocellulosic fibres from the oil palm biomass. A thorough understanding of oil palm biomass physical nature with its every possible industrial processing, is therefore a necessity towards successful development of an indigenous oil palm biomass processing machine. Hence, initiating a quest towards the development of the processing machine involving field studies conducted at commercial processing plants, assessment on key implementing agencies' involvement in oil palm biomass related R&D activities and adoption of Quality Function Deployment, a technique acknowledged for integrated product design and development. A three-stage processing is found as a pre-requisite to extract oil palm fibres while moisture level, purity and length are altogether considered being the fibres' critical characteristics toward specific end uses. Further, nine of the machine characteristics have been identified being the major specifications, leaving ten others as minor. Despite several shortcomings identified by the key agencies in the processing of oil palm biomass into fibres, findings from this study is envisaged to further catalyse the development of downstream industry from optimum utilisation of oil palm fibres for value-added products manufacture.

Keywords: Oil palm biomass, Lignocellulosic fibres, Processing machine, Quality Function Deployment

INTRODUCTION

Originated from the western part of Africa [1], oil palm (*Elaies guineensis*) was first introduced to Malaysia in the late 19th century [2]. The commercial exploitation of oil palm began in early 1900's but massive planting was only initiated by the government in the early 1960's, as an attempt to ease dependence on rubber as the major crop for export earnings [2]. The oil palm industry has then enjoyed a steady growth through decades of progressive developments and today, it emerges as one of the important sources of commodities to the country. The oil palm products' total export earnings for instance, had once reached a figure of more than RM21 billion in 1998 [3]. Whilst the sizable growth was associated with the high demands for crude palm oil (CPO) in various food and oleochemical industries [2], the industry also generates a substantial amount of biomass or solid by-products in the forms of trunks, fronds and empty fruit bunches (EFB). Extraction of CPO and crude palm kernel oil (CPKO) is however, constituted only about 10% of the oil palm industry's dry matters, while the remaining 90% are mainly underutilised biomass [3]. An evidence of the enormous potential commercial values should these materials be successfully converted into value-added products [4].

Comparable to that of lignocellulosic materials from wood [5, 6, 7], lignocellulosic fibres from oil palm biomass is therefore processable into value-added products. These include compost, mulch media, erosion control media, cushion, mattress, livestock's roughage, particleboard, medium density fibreboard (MDF), pulp and paper, laminated board as well as carbonised products, i.e., charcoal and activated carbon [3, 4, 8, 9, 10, 11]. The biomass however, required a totally different treatment regime to extract the fibres [12]. This is especially true when most of the common timber processing machines available are not compatible due to the biomass intrinsic properties. Those properties namely high moisture content, high variation of density and considerable sugars and silica contents [4, 5, 6, 13] have led to several difficulties which include accelerated microbial infiltration [6] on the processed biomass and rapid blunting of the cutting tools [14]. As a result, it impedes the production of high quality fibre strands, highly demanded for downstream activities [12].

Acknowledging the fact that majority of the wood-based industries in Malaysia are now extensively utilising rubberwood [5], oil palm biomass has therefore emerged as a strategic source of raw material considering the expected decline of timber resources (including rubberwood) supply in future [15]. This is substantiated by the statistics which predicted that availability of oil palm biomass will continue to increase annually [16, 17], resulted from more oil palm plantations being established nationwide [18]. From a total of merely 2.3 million ha in 1993 [19], the area planted with oil palm throughout Malaysia has increased significantly for the last three years, recording 3.4 million ha in 2000, 3.5 million ha in 2001 and rose to 3.67 million ha in 2002 [18, 20]. Whilst the trunks are available in every twenty five to thirty years' economic cycle of the oil palms due to replanting, the fronds are available through regular pruning in plantation and the replanting exercise [2, 6, 16]. EFB on the same note, is continuously generated from more than 300 palm oil mills operating over the country [18] throughout the year.

The progressive R&D efforts on oil palm biomass utilisation for the last fifteen years or more [4] have thus far witnessed the development of a few oil palm biomass processing technologies and a number of value-added products. These achievements however, have yet to reach the level of extensive technological exploitation at commercial arena. Most of the initiatives are focused at laboratory and pilot scales, with a few still at the small-scale [4] industry. While some processing technologies have been installed for commercial application, the rests are still not fully exploited. As such, emergence of such processing machine for oil palm biomass should, in the first place, be relevant to the commercial requirements and indigenous (to oil palm) in principle. Quest towards establishment of appropriate technical specifications of an indigenous oil palm biomass processing machine is indeed a consequence inspired from the difficulties encountered during the processing of oil palm biomass into lignocellulosic fibres. It involved a three-stage approach which incorporates understanding the industrial processing of oil palm biomass into fibres, assessment at key implementing agencies that involved in oil palm biomass related R&D activities and adoption of Quality Function Deployment (QFD) method, a technique acknowledged for integrated product design and development. It is envisaged that due to successfulness and robustness of QFD in various industrial applications [21, 22, 23, 24, 25], the technical specifications obtained would serve as a pivotal input in future development of oil palm biomass processing machines.

MATERIALS AND METHODS

The three-stage study approach began with understanding the fundamentals of extracting oil palm fibres from the biomass from the industrial standpoint. In this regard, field studies were conducted at two local commercially-in-practice oil palm biomass processing mills. Key observations made include mills' productivity and functionality as well as performance of the processing machinery installed.

The second stage was an assessment carried out at the leading agencies in Malaysia which are responsible or significantly involved in the processing and utilisation of oil palm biomass and fibres respectively. A questionnaire was formulated to facilitate information gathering amongst the selected agencies. A follow-up interview was then conducted at the respondents' premises. Two aims identified at this stage were: (i) to discover any shortcomings with regards to oil palm fibres commercial exploitation and (ii) to derived the desired primary requirements (PR) of an intended oil palm biomass processing machine which were then being used as input during the final stage.

The final stage was the transformation of industrial or end-user's requirements into technical specifications of an indigenous oil palm biomass processing machine through the adoption of QFD according to the House of Quality (HoQ) model [24]. In this regard, PR or the so called industrial expectations were transformed into specific target values equivalent to the processing machine's technical specifications through the systematic construction of eight HoQ compartments. Details about HoQ construction could be obtained from further readings of [24, 26].

RESULTS AND DISCUSSIONS

Results shown in Table 1 demonstrate that the end products' intended applications emerged as the governing factor for the type of processing lines used or installed at an oil palm biomass processing plant. While high quality fibres are meant for downstream applications, the inferior grade is produced merely for boiler fuel or fertilizer production. It is obvious that incorporations of a dryer or an agitator are needed in any mill, observed being the additional requirements depicted by the end fibres quality in meeting specific purposes. Meanwhile, moisture level, purity and length served as the fibres' key characteristics taken into consideration to determine its grade and possible applications.

Further, as both processing systems were benchmarked against the others [12], it can be deduced that commonly a minimum three-stage processing is required to extract the fibres for downstream applications (Table 2). These include biomass primary disintegration, fine particles isolation from the fibrous materials and moisture removal from the fibres. Hence, for such design and development of an oil palm biomass processing machine, one should not neglect the influence of end fibres quality towards downstreaming activities. Apart from the dryer and/or agitator, a baling machine is also noted to facilitate packaging, handling and transportation of the fibres.

Table 1: Field studies conducted at two oil palm biomass processing mills

Mill	Key processes * involved	Type of end product	End product quality
A	1. Pressing cum squashing 2. Beating cum splitting 3. Screening cum sieving 4. Force drying 5. Baling	Long and dried clean fibres	MS1408:1997(P) fully compliant: Fibre length: >56% above 100 mm Moisture content: <15% Impurities: <13%
B	1. Smashing cum beating 2. Squeezing cum cutting 3. Pressing cum twisting 4. Agitating	Short and moist-fibres with impurities	MS1408:1997(P) non-compliant: Moisture content: >45%

Note: * Two simultaneous processes indicated above are accomplished by a single machine

Table 2: Summary of processing mechanisms identified for oil palm lignocellulosic biomass

System's type	Raw material	Product's end use	Key processes involved
Proprietor 1 (mill A)	EFB	Downstream manufacturing	(Pressing + Squashing) → (Beating + Splitting) → (Screening + Sieving) → Drying → Baling
Proprietor 2 (mill B)	EFB	Boiler fuel	(Smashing + Beating) → (Squeezing + Cutting) → (Pressing + Twisting) → Agitating
Other [12]	EFB	Downstream manufacturing	Shredding → Hammermilling → Screening → Washing/Deoiling → Drying → Baling
Other [12]	(Trunks + Fronds)	Downstream manufacturing	Shredding → Hammermilling → Screening → Drying → Baling

With regards to oil palm fibres commercial exploitation, several shortcomings (Table 3) had been identified by key implementing agencies. Unconvinced market issue was closely referred to industries' refusal to use indigenous oil palm biomass processing machines. This is due to the fact that large scaled oil palm fibres-based industries are scarce. Furthermore, the wood processing machines (as opposed to oil palm's) are already proven for decades. As of oil palm trunks, its availability once in every 25 years rotation during the replanting exercise, has been too discrete. Effective and efficient dryer is highly desirable for oil palm fibres due to the presence of substantial amount of moistures in the biomass. Lack of large scaled processing machine for short fibres production correlates to the fact that oil palm fibres are best produced from a set of machines uniquely assembled in a processing line. The non-concerted efforts undertaken by key agencies toward exploiting oil palm fibres were possibly due to the fact that there are variations in agencies' roles and responsibilities. Current funding mechanism is also insufficient to conduct relevant basic studies, applied experiments and research-to-commercial transition attempts cohesively and concurrently.

Table 3: Selected shortcomings in oil palm fibres commercial exploitation

Respondent (type)	Description
R1 (PC)	Issue of unconvinced market
R2 (PC)	Availability of oil palm trunks of 25 years cycle and its scattered distribution nationwide
R3 (RI)	Drying of shredded fibres requires specially designed dryer for effective and efficient drying
R4 (RI)	No machine is able to produce short fibre strands at large scale due to the fibres' toughness
R5 (PC)	Incoherent research undertaken simultaneously by various organizations

Legends: PC: private company, RI: research institution

Table 4: Industrial expectations with regards to an indigenous oil palm biomass processing machine

Industrial requirements or expectations		Relative importance [27]
Primary requirements (PR)	Secondary requirements (SR) or elaborated needs	
Throughput capacity	More than 4 mt/hr biomass processing capacity	4.75
Reliability	More than 3 years' optimum operating performance	4.75
Functionality	Serviceable (fibres extraction) accurately	4.75
Versatility	Processing capability to all types of solid biomass	4.00
Mobility	Movable easily to serve various places	3.25
Easy to operate	User friendly operation for beginners	4.50
Safety	Sound safety features for novice operators	4.75
Cost effective	Low operating cost due to energy consumption	4.50
Availability	Uninterrupted operation within designated cycles	4.00
Maintenance	Maintainable by any skilled technician	4.25
Lifetime	More than 10 years' stable performance	4.50
Machine finishing quality	High precision fabrication and assembly	3.25
Processed material quality	Extracted fibres met standards' requirements	5.00
Power consumption	Functions at low power consumption	4.50
Spare parts and accessories availability	Parts replacement and supply easily accessible	4.00
Weight	Easily transportable from one site to another	2.50
Colour	Delivered with attractive coating and colour	2.00
Brand	Original equipment manufacturer (OEM) brand	2.00
Durability	Lasting performance with minimal wear and tear	1.00
After sales service	Technical supports throughout machine's lifetime	0.75

Table 4 explicates an example of one-to-one PR to SR expansion, i.e., initial step in QFD analysis. Indicated values of relative importance of all PR are reflection of ratings between "undesirable" and "critical" of 1 to 5 scoring respectively [27]. These are average scorings given by participating engineers and/or scientists during the assessments. All SR or elaborated needs are obtained upon relating the respective PR's associated parameters against the biomass supply and processing traits. Henceforth, maximum scoring attained by "processed material quality," concurred with outcome from the field studies conducted at two oil palm biomass processing mills.

The route in which the technical specifications of an indigenous oil palm biomass processing machinery being established through HoQ compartments' systematic construction is best depicted by HoQ's exploded view of Figure 1. From a total of 20 CR, 19 EC were being established. Albeit operating on different principles, four machines of identical processing purpose, were chosen for two methodical benchmarking exercises [27] involving CR and the targeted EC. The target values, placed at the bottom most of HoQ, finally expose the refined specifications or namely EC of an indigenous oil palm biomass processing machine. Table 5 discloses nine major specifications obtained from a total of 19 EC in culmination of field studies and technical assessments conducted at commercial biomass processing mills and key implementing agencies respectively.

All in all, the quest for technical specifications of an indigenous oil palm biomass processing machine has been exemplified through amalgamation of field studies on the biomass industrial processing, technical assessments at key implementing agencies and adoption of fundamental design method, i.e., QFD. As such, a testimony of a typical industrial requirements transformed into machine's technical specifications. Nonetheless, as this study has detected drawbacks from the incomplete machine's production planning and fabrication processes, further research and development work is therefore a necessity to put the design specifications into the appropriate application perspective.

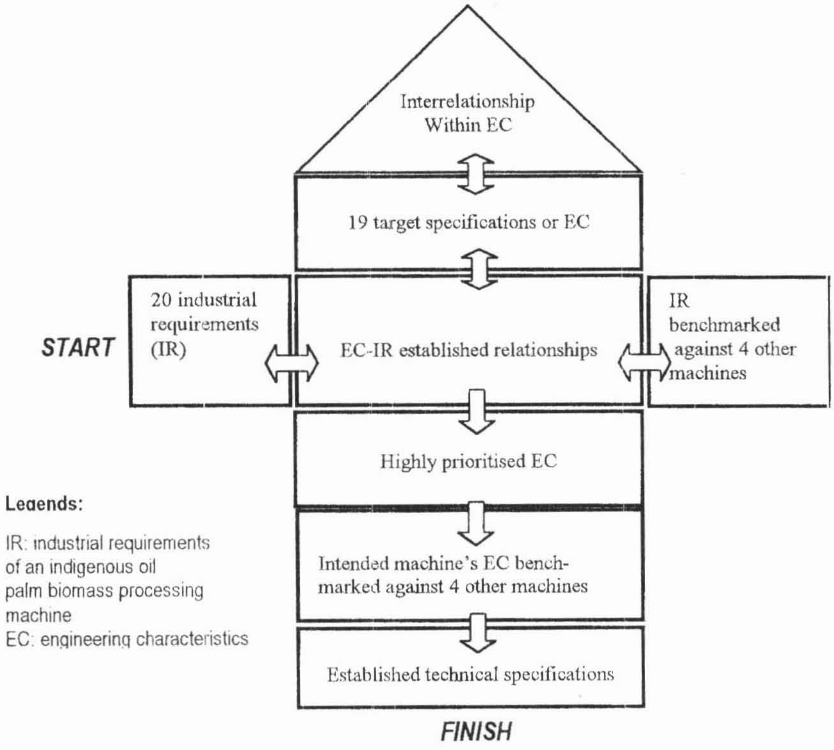

Figure 1: Exploded view of HoQ showing the step-by-step technical specifications establishment

Table 5: Selected technical specifications for an indigenous oil palm biomass processing machine

No.	Description
1.	Tested at machine's full load of 6.0 mt/hr processing capacity
2.	Availability of a comprehensive handling/operating, servicing and troubleshooting manuals as the machine's technical support
3.	Employs a robust extraction mechanism incorporating a combined smashing, shredding and cutting principles
4.	Low changing frequency of cutting material due to wear and tear
5.	High flexural strength drive shaft, made of Cr-Mo based type of steel
6.	High abrasive resistance cutting material made of Si-Mn based type of steel
7.	High thermal resistance cutting material made of Si-Mn based type of steel
8.	Large inlet chute's cross section area for raw material feeding of 0.8 m^2
9.	Large fibres extraction compartment of 0.7 m^3

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REFERENCES

1. Moll, HAJ. 1987. The economics of oil palm. *Economics of Crops in Developing Countries*, Pudoc Wagenigen, Netherlands, no. 2. In *Khozirah and Khoo, Introduction, FRIM Research Pamphlet*, Kuala Lumpur, FRIM, January 1991, no. 107, p. 3-4

2. Khozirah, S. and Khoo, KC. 1991. Introduction. In *Khozirah et al., eds., Oil palm stem utilisation: review of research, FRIM Research Pamphlet,* Kuala Lumpur, FRIM, January 1991, no. 107, p. 1-10

3. Yusof, B. and Mohamad, H. 2000. Utilisation of oil palm biomass: strategic progress report. In *Wan Asma et al., eds., Proceedings of 5th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, December 2000, p. 1-6

4. Abdul Razak, MA. and Mohd Nor, MY. 2000. Recent advances in the commercialisation of oil palm biomass. In *Wan Asma et al., eds., Proceedings of 5th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, December 2000, p. 7-15

5. Yusof, B. and Mohamad, H. 1999. Availability, extraction and economics of oil palm biomass utilization. In *Jalaluddin et al., eds., Proceedings of 4th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, 1999, p. 3-15

6. Salleh, MN. 1995. Oil palm residues: challenges towards industrial exploitation. In *Koh et al., eds., Proceedings of 3rd National Seminar on utilisation of oil palm tree and other palms*, Kuala Lumpur, June 1995, p. 1-18

7. Khoo, KC., Killmann, W., Lim, SC. and Halimahton, M. 1991. Characteristics of the oil palm stem. In *Khozirah et al., eds., Oil palm stem utilisation: review of research, FRIM Research Pamphlet,* Kuala Lumpur, FRIM, January 1991, no. 107, p. 15-28

8. Dahlan, I. 2000. Oil palm frond: from waste material to commercial feed. In *Wan Asma et al., eds., Proceedings of 5th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, December 2000, p. 76-86

9. Kim, JJK., Koo, BT., Teo, VK. and Liew, ASB. 1999. Bioconversion of oil palm mill wastes to bioorganic fertiliser using in-vessel composting. In *Jalaluddin et al., eds., Proceedings of 4th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, 1999, p. 184-188

10. Wan Asma, I., Wan Rasidah, K., Khozirah, S., Rozita, A. and Abu Said, A. 2000. Utilisation of oil palm empty fruit bunches for growing plants on BRIS soil - a preliminary study. In *Wan Asma et al., eds., Proceedings of 5th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, December 2000, p. 223-230

11. Wan Asma, I., Wan Rasidah, K. and Lim, SH. 1999. Mulching mat from oil palm empty fruit bunches. In *Jalaluddin et al., eds., Proceedings of 4th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, 1999, p. 189-193

12. Mahmudin, S. and Mohd Nor, MY. 2000. The relevance of indigenous processing machinery for oil palm biomass as raw material for the wood-based industries. *Malaysian Science and Technology Congress, Symposium C: manufacturing and processing technology*, Genting Highlands, 2000

13. Rahim, S. 1996. Development, properties and durability of oil palm fibre cement composite. *Ph.D. thesis*, University of Sheffield, December 1996, p. 76-99

14. Ho, KS. and Hong, LT. 1991. Processing and protection of oil palm stems. In *Khozirah et al., eds., Oil palm stem utilisation: review of research, FRIM Research Pamphlet*, Kuala Lumpur, FRIM, January 1991, no. 107, p. 29-34

15. Norini, H. and Midmore, P. 2000. The role of oil palm residues in the development of Malaysian forest-based industries. In *Wan Asma et al., eds., Proceedings of 5th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, December 2000, p. 64-75

16. Norini, H., Wan Asma, I. and Mohd Azmi, MI. 1999. Availability of oil palm residues in Peninsular Malaysia. In *Jalaluddin et al., eds., Proceedings of 4th National Seminar on utilisation of oil palm tree*, Kuala Lumpur, 1999, p. 16-24

17. Kamarudin, H., Mohamad, H., Arifin, D. and Jalani, S. 1997. An estimated availability of oil palm biomass in Malaysia. *PORIM Occasional Paper*, Kuala Lumpur, PORIM, June 1997, no. 37.

18. MPI. 2001. *Report on Malaysia's primary commodities*, Kuala Lumpur, Ministry of Primary Industries Malaysia, December 2001, 9th Issue, p. 1-39

19. MPI. 1994. PORLA palm oil statistics. Kuala Lumpur, Ministry of Primary Industries Malaysia, 1994, 14th edition.

20. MPOB. 2003. *Malaysian oil palm statistics 2002*, Kajang, Selangor, Malaysian Palm Oil Board, 2003, 22nd ed., p. 1-51

21. Mazur, GH. 1994. QFD outside North America: current practise in Europe, the Pacific Rim, South America and points beyond. *Proceedings on 6th Symposium on Quality Function Deployment*, Novi, Michigan, 1994, p. 3-9

21. Zairi, M. 1993. Quality function deployment: a modern competitive tool. *European Foundation Quality Management*, 1993, TQM Practitioner Series.

23. Akao, Y. 1990. Quality function deployment: integrating customer requirements into product design. Portland, Oregon, Productivity Press, 1990.

24. Hauser, JR. and Clausing, D. 1988. The house of quality. In *Designing new products*, Harvard Business Review, 1990, p. 29-39

25. Sullivan, LP. 1986. Quality function deployment. *Quality Progress*, 1986, vol. 19, no. 6., p. 39-50

26. Cohen, L. 1995. Quality function deployment: how to make QFD work for you. *Engineering Process Improvement Series*, Addison-Wesley Publishing Company, 1995.

27. Ginder, DA. and Donofrio, NMJ. 1991. The strategic approach to market research. *Proceedings on 3rd Symposium on Quality Function Deployment*, Novi, Michigan, 1991, p. 418-427