Research Article

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Design guidelines for sustainable utilization of agricultural appropriate technology: Enhancing human factors and user experience

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Abstract: The utilization of appropriate technology (AT) has become the Indonesian government strategy to increase productivity of agricultural commodities due to its simplicity and cost-effectiveness. However, the current utilization of AT remains suboptimal mostly due to design deficiencies that insufficiently account for human factors and user experience. In response, the aim of this study is to establish comprehensive AT design guidelines for sustainable AT utilization, focused on agricultural processing machines. An intensive observation was initially conducted in a rural community in Indonesia, to summarize difficulties faced by AT users. Supported by an exhaustive review of literature, a total of 44 human factors related design criteria were defined. Subsequently, these criteria underwent rigorous validation through a questionnaire administered to 197 respondents, consisting of AT designers, experts, and users. Employing the framework of principal component analysis (PCA), novel dimensions of AT design criteria were suggested, encompassing safety and error prevention, functionality and economics, user-friendly, low physical effort, physical workspace compatibility, and perceptible information. To augment the insights gleaned from the PCA, a matrix of importance-performance analysis was created, affording a map of the relative significance and concurrent performance of the defined criteria. The implications of this study are further discussed.

Keywords: appropriate technology, human factors, design criteria, principal component analysis, agricultural processing machines

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1 Introduction

The concept of appropriate technology (AT) was introduced around 1973 with the term of "Intermediate Technology" [1]. AT refers to simple and low-cost technology designed to address the needs of low-income communities in developing countries, particularly for small-scale utilizations, with the aim of increasing productivity and reducing the reliance on manual work [2]. AT emphasizes the utilization of local materials and resources, capitalizing on the inherent strength of the local context [3]. Often, AT solutions are developed based on the skills and capacities within a community. Bakker [4] extends the concept by defining any technology that positively impacts meeting basic human needs as falling under the category of AT.

The potential benefits of AT have been acknowledged by the Indonesian government. As an agrarian country, Indonesia relies heavily on the agricultural sector, which plays a pivotal role in its economy. This sector not only provides employment opportunities for nearly half of the population but also contributes to around one-fifth of gross domestic product and serves as a substantial source of exports [5]. Due to limited technological availability, the development of AT emerges as a national strategy. AT is expected to reduce operating cost of agricultural processing machines that currently still constitute 30–40% of the total production expenses [6]

Paradoxically, the utilization of AT remains modest in Indonesia. While the governments have introduced various AT machines, practical challenges have hindered their seamless integration into agricultural practices. Based on our observation, there are significant design challenges that need to be addressed. The prevalent design of agricultural AT often prioritizes economic cost–benefit analyses, assuming that users will maximize the utilization of ATs regardless of their design quality, as mentioned by Syuaib et al. [7]. AT designers seem to emphasize technical aspects while sometimes overlooking usability issues [8]. Other studies have identified other factors contributing to the low effectiveness of AT, including the absence of practical and gender-friendly design, socio-cultural barriers [9], high operational cost [10], and a failure to incorporate considerations of operational risks inherent in the machine design [11].

Meanwhile, certain investigations have embraced a human-centered approach in designing AT machines, such as grain thresher [12], maize dehusker-sheller [13], sickles [14], and cookstove [15]. However, despite these efforts, comprehensive reports detailing specific design guidelines that served as the foundation for AT designs are largely absent from the literature. There is a further need for recognizing the necessity of human factors and user experience as the key to successful AT implementation, including the concept of user-centered design, emphasizing user attributes [16] and usability [17–19].

In the realm of AT, discussions surrounding AT design criteria for agricultural product processing are relatively scarce. Indonesia's diverse AT users necessitate design criteria that are ergonomic, secure, user-friendly, and tailored to the distinctive characteristics of indigenous users. An integration of the concepts of user-centered design, usability, and universal design can be applied as the initial model of AT design principles, providing a foundation for contextually-relevant AT design.

Previous researchers have attempted to formulate criteria for designing and evaluating AT and agriculture. One such researcher is Sianipar et al. [20], who presented factors that need to be considered in the design of AT, including technical, economic, environmental, and social considerations. Moses et al. [8] specifically developed evaluation criteria for cookstoves. These criteria place a focus on usability aspects, including fuel convenience, cooking performance, operability, maintenance, comfort, and location-specific requirements. Other criteria were proposed by Valizadeh and Hayati [21], emphasizing sustainability aspects, such as social equity and well-being, durability, stability and compatibility, and productivity and efficiency.

Principal component analysis (PCA) is a method used to reduce the dimensions of a dataset. The main idea behind PCA is to reduce the dimensionality of a dataset consisting of many interconnected variables while preserving as much variation as possible [22]. Valizadeh and Hayati [21] used PCA to develop and validate an agricultural sustainability measurement index in Iran, while Andati et al. [23] employed PCA alongside a multivariate probit regression model to investigate the factors influencing the adoption of climate-smart agriculture among small-scale potato farmers in Kenya.

This research endeavors to fill the existing problem by delineating a comprehensive framework of AT design criteria that align seamlessly with the socio-cultural fabric, user experience, and the practical realities of the agricultural landscape in Indonesia. Through the synthesis of human factors and user experience, this study seeks to set forth a pioneering path toward increasing utilization of AT in the agricultural sector.

2 Methodology

This research is structured into three distinct stages: an evaluation of the current utilization of AT, the formulation of design principles, and the evaluation of AT design criteria. In the initial phase of the study, a preliminary examination was conducted to delineate the existing characteristics of AT machines in Indonesia and appraise their level of utilization. This preliminary study entailed field observations, a data collection methodology involving direct observation of on-site situations or events.

The second stage entails the formulation of design principles, tailored to the unique context of AT within Indonesia. PCA method serves as the basis of this developmental phase. Progressing to the third stage, the evaluation of AT design criteria is analyzed employing the robust methodology of Importance-Performance Analysis (IPA). By dissecting the dimensions of importance and performance, the IPA approach aids in identifying the optimal strategies for fostering substantial improvements in AT utilization.

2.1 Research development on AT

An intensive literature study was conducted on the Scopus database using the following keywords: AT, agricultural processing machine design, and ergonomics. The obtained documents were analyzed using VOSviewer software. As shown in Figure 1, there are five clusters, which include: (1) AT, product design, and ergonomic design; (2) humans, risk factors, and body posture; (3) musculoskeletal disorders (MSDs), risk assessment, and occupational risks; (4) ergonomics; and (5) anthropometry. It is clear that ergonomic-related issues are relevant to the design of AT.

2.2 Field observation

The process of observation was executed through a combination of direct field observations and insightful

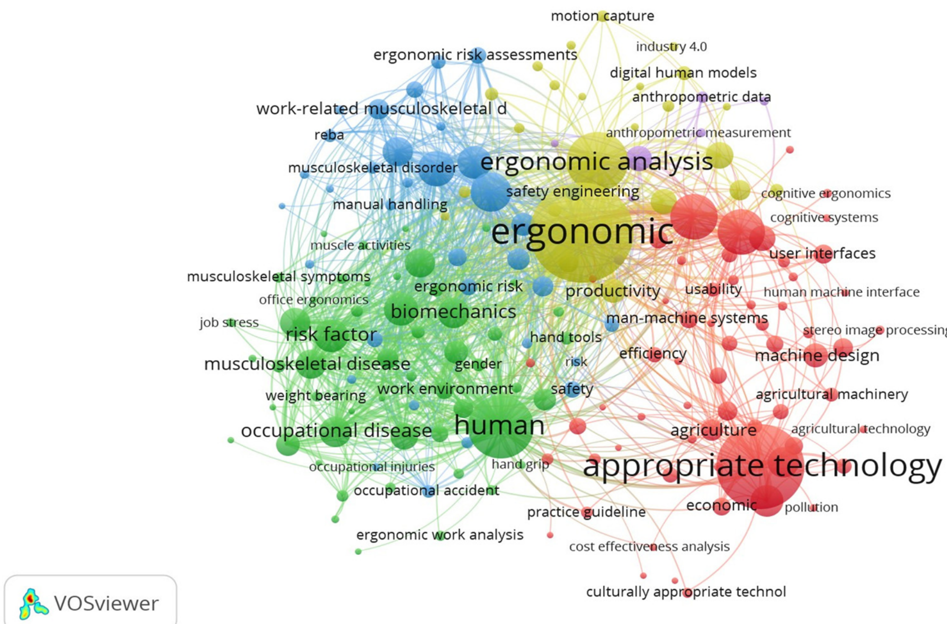

Figure 1: Keywords mapping on bibliometrics.

interviews with users of AT machines, particularly those related to agricultural product processing. The focal point of these observations was a farming community located in Subang, West Java, Indonesia. In particular, the investigation centered around four distinct small-medium enterprises (SMEs), the profiles of which are meticulously outlined in Table 1.

2.3 Development of design criteria

The criteria for AT design consist of a set of principles for human–machine interaction that can serve as a guide in designing AT machines that have positive effects on usability, acceptability, and utility, leading to enhanced user productivity. Various concepts related to product design were comprehensively used, including user-centered design, universal design, safety, and usability. The initial factors in this study were identified based on the literature reviewed during the primary model-building stage. The initial factors are determined by combining and selecting reference model variables relevant to the AT problem.

The results of the previous literature study, which involved the establishment of the initial research factors, were then followed by the identification of model indicators. A total of 105 design indicators have been documented. Ultimately, after verification through field observations and interviews with 4 SMEs, a total of 44 design indicators were selected. Numerous AT design guideline indicators were gathered from previous articles [8,16–19,24–32].

2.4 Questionnaire

This study utilized a questionnaire as a measurement tool to acquire the necessary data, supplementing the results of

Table 1: Profile of SME respondents

SME name	Year of establishment	Number of employees	Production capacity	Product
Enos	2013	4 people	15 kg dodol/day	Red beans dodol
Aitamie	2018	2 people	10 kg noodles/day	Corn flour noodles, corn flour chips
Mekar Sari	1997	10 people	200 kg pineapples/day	Pineapple dodol, pineapple crackers, pineapple wajit, pineapple jam, mushroom
Alam Sari	1997	25 people	20 tons pineapples/month	Pineapple dodol, pineapple crackers, pineapple chocolate, pineapple syrup, pineapple juice, mushroom

direct observations, to ascertain the relevance of design principles to the AT conditions in Indonesia. The initially prepared questionnaire underwent a pilot test with several respondents. The questionnaire encompassed 44 questions (based on the 44 design criteria) aimed at gauging user expectations and perceptions regarding AT design. Each factor was assessed using a Likert scale ranging from 1 to 5, with assistance provided to participants as needed.

The collected questionnaire data underwent validity and reliability tests. The validity test employed a correlation analysis by comparing the calculated *r*-value against the total-Pearson correlation at a 95% confidence level, demonstrating the validity of all research indicators. The reliability test yielded a Cronbach's alpha value of 0.968 (above 0.60), affirming the reliability of all indicators.

Factor analysis was utilized to establish the dimensions of AT design, using the PCA method to recognize patterns within multidimensional data. The application of PCA is expected to result in new criteria for the dimensions of the design guideline. Subsequently, these new dimensions were incorporated into an IPA matrix. The IPA matrix serves as an evaluative tool to pinpoint attributes necessitating enhancement and corrective measures, and was used to determine the priority of improvements based on machine design indicators in order to increase users' satisfaction. AT user satisfaction can be measured by comparing the performance of AT equipment expected by users compared to the actual performance of AT equipment in the field.

Table 2: Respondents' demography profiles

Criteria	Category	Frequency	Percentage (%)
Gender	Male	97	49.24
	Female	100	50.76
Age	16–25 years	68	34.52
	26–35 years	30	15.23
	36–45 years	58	29.44
	46–55 years	24	12.18
	>55 years	17	8.63
Education	Primary school	1	0.51
	Juniors high school	3	1.52
	High school	69	35.03
	Diploma	23	11.68
	Bachelor's degree	44	22.34
	Postgraduate	57	28.93
Use of AT	0–1 year	75	38.07
	1–5 years	60	30.46
	5–10 years	28	14.72
	>10 years	33	16.75

2.5 Respondents

A total of 197 respondents participated in the study, including AT operators, designers, SMEs, and farmers. The respondents were selected through purposive sampling from several regions in Indonesia, although the majority (81.09%) resided in West Java due to the rapid development of AT in that region. There were 89 male and 91 female respondents, with respondents aged between 36 and 45 years making up around 32.2% of all respondents and about 9.44% of respondents aged over 55 years. Most respondents had a college education background (Diploma-Postgraduate), around 69.44%, and only one was an elementary school graduate. When the survey was conducted, around 35.29% of respondents had used AT for 1–5 years, and around 20.00% had used AT for over 10 years. Table 2 shows the demographic data of the respondents.

3 Result and discussion

3.1 Summary of observation result

The outcomes of interviews and field observations conducted with AT users are outlined below.

3.1.1 Enos

In 2017, Enos received AT machines, including a coconut grater, peanut grinder, and dodol mixer (Figure 2), which almost doubled their production capacity. The machines are generally easy to use but cannot be repaired or modified if they are damaged. The design problems found include the short size/height of the coconut grater, which requires users to bend over, and the unprotected edges of the coconut grater that can cause hand injuries. Additionally, the inlet hole of the peanut grinder is too small, making it impractical.

3.1.2 Aitamie

Aitamie, established in 2018, produces non-wheat noodles and pasta using AT machines, some of which are shown in Figure 3. The owners reported that the AT machines have benefits in maintaining production quality, but some machines require physical exertion and are uncomfortable, especially for women. Minor accidents have occurred, such as hands getting caught in the machines. Specific complaints were also

Figure 2: Various AT machines at Enos.

mentioned, such as the lack of temperature control on the extruder, which results in easily cracked noodle products. The tool must be disassembled when cleaning, which is inconvenient, and the extruder intake hole is too high anthropometrically, requiring a ladder. Furthermore, the electric power consumption of the extruder is still too high, increasing production costs.

3.1.3 Mekar Sari

Mekar Sari has been utilizing AT machines for pineapple processing since 2019. It is worth noting that Subang is known for its pineapples. The owner is satisfied with the use of the AT machines (Figure 4), which have increased production capacity by around 50%. However, several machines are still semi-manual, and problems have arisen with their use, including complaints related to musculoskeletal pain, difficulties in repairing the machines, and the lack of safety measures. In addition, they have reported that using gas fuel for the dodol mixer is not cost-effective compared to traditional wood stoves since the temperature is not optimal, and the process takes longer.

3.1.4 Alam Sari

Alam Sari has been using AT machines for pineapple processing since 2005. The AT machines owned by Alam Sari include a chopper, dodol mixer, slicer, coconut grater, packer, extractor, mixing tank, cooking tank, and pulper (Figure 5). The owners have received benefits from using AT machines, including faster production times, larger production capacity, and cheaper production costs. In general, AT machines are easy to use, except for several tools that require special skills, such as automatic packaging tools.

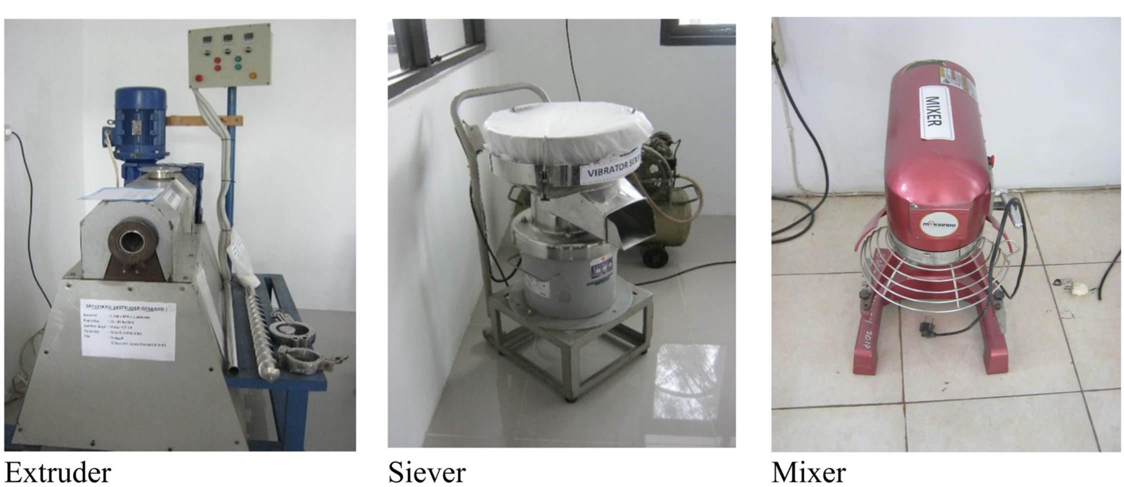

Figure 3: Various AT machines at Aitamie.

Figure 4: Various AT machines at Mekar Sari.

However, they have also revealed several design problems, such as:

- Chopper (a tool for making pineapple pulp). The machine is often exposed by the pineapple pulp resulting in easy machine damage.
- Dodol mixer does not have dispensing system. After completion of mixing process, users have to dissemble the machine and it seems to be a hassle for women.
- Alam Sari has received assistance from the government with a set of machines such as cold storage and cooking tanks. However, the machines are no longer used since their capacities are too big and high electric power is required (10,000 W).
- Several processes are still conducted manually such as using a knife to peel and cut pineapples. With a production capacity of around 500–600 kg of pineapples per day, the manual process takes a lot of time and effort.

Based on field observations, some existing problems in using AT machines can be summarized as follows:

- Functionality: Functionality refers to the ability of a machine to meet basic requirements and function properly [33]. Our observations showed that most AT machines function acceptably, but some require improvements in design to enhance performance, shorten processing time, and increase productivity.
- Physical workload: The most common problem with current AT machine design is the lack of ergonomic aspects. The disproportionate height of machines requires workers to bend down every time they put in raw materials and take out processed products, leading to physical fatigue and the risk of musculoskeletal injury. Improving the design to be compatible with users' needs can increase effectiveness, productivity, and prevent health problems [34].
- Energy use: Users often complain about the cost of energy use during the cooking process. For example, the cooking time using a gas-fueled mixer was longer than that using a wood stove due to less optimal fire processes. Some AT machines still use diesel engines, which are less environmental-friendly and more

Figure 5: Various AT machines at Alam Sari.

expensive compared to electricity. Fuel type and heater design have been shown to affect fuel cost and cooking time in previous studies [35].
- Safety and errors: The use of agricultural machinery has been reported to cause traumatic injury incidents to users, indicating that safety is often ignored in designing AT machines [12]. In case of errors, the handling procedure should have a clear standard operating or emergency procedure.
- Maintenance and repairs: The existing design makes cleaning, maintaining, and repairing AT machines difficult. Therefore, machines must be easily disassembled to ease the cleaning process. The repair process of some AT machines can only be done by a technician, but the availability of repair workshops is limited, especially in rural areas.
- User convenience: Ease of use of AT machines varied from very easy to rather difficult. Simple and manual machines are generally easier to use because users can

Table 3: Min., max., mean values, and standard deviation (SD)

Items		Min. value	Max. value	Mean value	SD
X1	Consideration of socio-cultural factors of the local community	3	5	4.3	0.67
X2	Usable by various groups	1	5	4.0	0.86
X3	Understandable by various groups	1	5	4.3	0.71
X4	Ability to choose to use	2	5	4.1	0.74
X5	Simple to use	2	5	4.3	0.68
X6	Easy to set-up	3	5	4.4	0.60
X7	Comfortable to use	3	5	4.4	0.64
X8	Minimizes mental effort	1	5	4.3	0.74
X9	Easy to use	3	5	4.4	0.61
X10	Grouped buttons and indicators for easy use	3	5	4.4	0.63
X11	Provides a manual guide	1	5	4.3	0.73
X12	Manual guide available in different forms	1	5	4.3	0.70
X13	Important information is easy to be understood	1	5	4.4	0.67
X14	Important information is easy to read and is clear	1	5	4.4	0.65
X15	Has a cancellation feature	1	5	4.2	0.86
X16	Emergency controls can be identified	1	5	4.2	0.79
X17	Dangerous parts are protected	2	5	4.4	0.76
X18	Has warnings of potential hazards	1	5	4.3	0.82
X19	Has prevent-errors features	1	5	4.3	0.78
X20	Has a safety and security guide	1	5	4.4	0.80
X21	Does not cause pain or injury in the hands or feet	1	5	4.2	0.76
X22	Minimizes physical effort	1	5	4.2	0.73
X23	Long-term use without causing fatigue	1	5	4.2	0.79
X24	Long-term use without causing pain	1	5	4.2	0.84
X25	Long-term use without requiring a long rest period	1	5	4.1	0.81
X26	Accessibility of all parts	2	5	4.3	0.66
X27	Matching the user's body size	2	5	4.2	0.74
X28	Matching various characteristics of the user's body	2	5	4.2	0.73
X29	Can be operated in a comfortable standing or sitting position	1	5	4.1	0.77
X30	Usable by users with a variety of hand sizes and palm grips	2	5	4.2	0.64
X31	Safe to use	3	5	4.5	0.63
X32	Environmentally friendly	3	5	4.5	0.62
X33	Noise level below the threshold	2	5	4.3	0.75
X34	Meets applicable standards	1	5	4.3	0.74
X35	Has long enough durability	2	5	4.4	0.69
X36	Affordable price	1	5	4.2	0.80
X37	Easy to maintain	2	5	4.4	0.68
X38	Uses good quality materials	2	5	4.3	0.66
X39	Attractive design	2	5	4.1	0.80
X40	Simple construction	2	5	4.2	0.75
X41	Easy to clean	2	5	4.3	0.65
X42	Easy to repair	2	5	4.3	0.68
X43	Has a modular design	1	5	4.2	0.77
X44	Efficient energy use	2	5	4.3	0.64

apply them directly without learning or training. Ease of use is a key factor in using technology, as it is closely related to the usability of a product or design [33].
- Dimension: The size of AT machines is also an important issue raised by SMEs. In rural areas, simple, light, and easy-to-move machines that require a small space to operate are very helpful. Developing a design with mobility advantages is one of the most effective, economical, and efficient solutions that can enhance the immediate post-harvest process.

3.2 Descriptive statistics

The descriptive statistics questionnaire measurement results are shown in Table 3. The design indicators in Table 3 were obtained from the combined results of literature studies and field observations. The literature study yielded 105 design criteria. After verification with the results of initial observations and interviews, 41 criteria were selected that were relevant to the conditions, use, and problems of AT in the field. Results showed that safe to use and environmental-friendly had the highest mean values (4.5 ± 0.63 and 4.5 ± 0.62, respectively) and usable by various groups had the lowest mean value (4.0 ± 0.86) (Table 3).

3.3 Results of factor analysis

An exploratory factor analysis was conducted on the data using PCA with factor extraction and VARIMAX rotation. The questionnaire data underwent significance testing using Bartlett's test of sphericity and the sampling adequacy test using the Kaiser–Meyer–Olkin (KMO) test. The results of the tests indicate that the significance level is less than 0.05 (Sig. = 0.000), and the variables used can proceed to the next process. The KMO test also yielded a value of 0.927, indicating that the factor analysis process is feasible (Table 4).

The results of the factor analysis show that, based on the users' opinions, six factors affect the optimum design of AT. The factor loadings, communalities, variance explained and eigen values are presented in Table 5. The six factors resulting from the interrelationships of each indicator are safety and error prevention, functionality and economics, user-friendliness, low physical effort, physical workspace compatibility, and perceptible information.

The percentage of variance shows that the first to sixth factors have variances ranging from 7.55 to 14.52% (Table 6). The cumulative variance of all the formed factors is 62.34% (>50%). The validity test and the reliability of each PCA showed that all factors were valid and reliable (Cronbach's alpha > 0.6).

The first factor is safety and error prevention. The safety and error prevention factor had 14.52% of total variance. This factor had the most significant effect. Based on the first factor, safety and error prevention, it is assumed that the AT design can minimize the dangers and negative consequences of accidents and unintentional actions. It should also provide warnings for potential hazards and errors, features that do not allow failure or safety even though they cannot work and prevent actions that are carried out unconsciously [17]. The design also needs to consider the safety and risks posed by AT machines.

The second factor is functionality and economics. This factor had 12.75% of total variance. According to the functionality and economic factor, someone will adopt technology when there is technical and physical support [36]. Currently, most AT machines are commercially oriented and mass-produced. Therefore, the economic and cost factors of AT machine will be important by considering the purchasing power of users in Indonesia and the functionality of the products. The design also allows the use of a modular system which makes it easy to move, clean, assemble, maintain, repair, and be adapted to the working environment conditions. AT machine is expected to use quality materials and energy sources that are cheap and available on site. The economic factors for AT machine are influenced by investment and operating costs, including energy and maintenance needs. Verma & Sinha [37] discovered that economic factors affect the acceptance of technology by farmers.

The third factor is user-friendly. This factor had 9.38% of total variance. The AT design needs to be practical, easy to understand, and easy to use. It is also necessary to consider local social conditions, culture, customs, perceptions, and behaviors for easy acceptance, adoption, use, and learning by people with various demographic backgrounds. According to Sonderegger and Sauer [38], socio-cultural background affects the usability assessment of a product. AT machines will be used by a great diverse of Indonesians who are socially and culturally different; therefore, developers need to consider these peculiarities when designing the machine.

Table 4: KMO and Bartlett's test

KMO measure of sampling adequacy		**0.927**
Bartlett's test of sphericity	Approx. chi-square	6676.560
	df	946
	Sig.	0.000

Table 5: Factor analysis results (factor loadings > 0.4)

Factor	Items		Factor loading	Communalities
Safety and error prevention	X15	Has a cancellation feature	0.607	0.714
	X16	Emergency control can be identified	0.713	0.772
	X17	Dangerous parts are protected	0.755	0.763
	X18	Has warnings of potential hazards	0.773	0.786
	X19	Has prevent-errors features	0.714	0.655
	X20	Has a safety and security guide	0.784	0.785
	X31	Safe to use	0.516	0.674
	X32	Environmentally friendly	0.567	0.690
	X34	Meets applicable standards	0.661	0.669
Functionality and economics	X35	Has long enough durability	0.662	0.654
	X36	Affordable price	0.698	0.657
	X37	Easy to maintain	0.701	0.731
	X38	Uses good quality materials	0.636	0.642
	X39	Attractive design	0.599	0.647
	X40	Simple construction	0.472	0.662
	X41	Easy to clean	0.573	0.721
	X42	Easy to repair	0.671	0.730
	X43	Has a modular design	0.689	0.642
	X44	Efficient energy use	0.662	0.685
User-friendly	X5	Simple use	0.754	0.677
	X6	Easy to set-up	0.687	0.699
	X7	Comfortable to use	0.567	0.637
	X8	Minimizes mental effort	0.438	0.583
	X9	Easy to use	0.710	0.699
	X10	Grouped buttons and indicators for easy use	0.684	0.697
Physical workspace compatibility	X27	Matching the user's body size	0.699	0.651
	X28	Matching various characteristics of the user's body	0.791	0.769
	X29	Can be operated in a comfortable standing or sitting position	0.695	0.753
	X30	Usable by users with a variety of hand sizes and palm grips	0.754	0.715
Low physical effort	X21	Does not cause pain or injury in the hands or feet	0.790	0.815
	X22	Minimizes physical effort	0.634	0.665
	X23	Long-term use without causing fatigue	0.679	0.726
	X24	Long-term use without causing pain	0.684	0.732
	X25	Long-term use without requiring a long rest period	0.694	0.700
	X26	Accessibility of all parts	0.403	0.683
Perceptible information	X2	Usable by various groups	0.566	0.505
	X11	Provides a manual guide	0.668	0.714
	X12	Manual guide available in different forms	0.704	0.795
	X13	Important information is easy to be understood	0.557	0.651
	X14	Important information is easy to read and is clear	0.685	0.748

The fourth factor is physical workspace compatibility. This factor had 9.13% of total variance. Based on the fourth factor, the AT design must accommodate various individual preferences and capabilities. This principle accommodates various circumstances and individual abilities to provide choices in the method of using a product, options for right or left-hand access, variations in hand sizes and grip sizes, and facilities for proper use.

The fifth factor is low physical effort. This factor had 9.01% of total variance. An AT design must be used efficiently and comfortably with a minimum physical fatigue, which allows users to maintain a neutral body position, use a reasonable mode of device operation, minimize repetitive actions, and reduce continuous physical effort. Based on our ergonomics assessment on the risk of MSDs of operating an AT machine, namely, the extruder, using the REBA method showed that the risk level is high. When operating the extruder, the farmers have to bend their body due to the extremely low position of the dough intake hole and product output. This could lead to complaints on the neck, shoulders, back, waist, and arms [39].

The sixth factor is perceptible information. This factor had 7.55% of total variance. The AT design needs to have a manual (manual book) on how to use the machine for easy

Table 6: Extracted factors and their eigenvalue, percentage of eigenvalue's variance, cumulative percentage, and Cronbach's alpha

Factors		Eigenvalue	Percentage of eigenvalue's variance	Cumulative percentage	Cronbach's alpha
F1.	Safety and error prevention	6.389	14.52	14.52	0.936
F2.	Functionality and economics	5.609	12.75	27.27	0.92
F3.	User-friendly	4.129	9.38	36.65	0.863
F4.	Physical workspace compatibility	4.018	9.13	45.78	0.88
F5	Low physical effort	3.962	9.01	54.79	0.895
F6.	Perceptible information	3.322	7.55	62.34	0.853

understanding by various users to minimize errors and confusion. Therefore, the machine that is made must have the ability to effectively communicate the required information to the user without considering the surrounding conditions or the user's sensory abilities. Information contained on AT machine can be in writing or non-verbal graphic symbols form. Non-verbal symbols are considered more effective than writing because they can easily be remembered and quickly communicate concepts and instructions. They also avoid problems due to impaired reading skills (children, elderly, and illiterate) or different languages [40].

The proposed six design principles have accommodated safety, functionality, economic value, physical workload, and user-friendly. Similar factors have been proposed by Beecher and Paquet [24]. Lin and Wu [27] mentioned aspects of functionality, social, commercial, and aesthetic. Our previous study has also included adaptability as additional factor [41]. The results of this research differ slightly from those of a study by Kuijt-Evers et al. [42], which identified six factors to consider in the design of hand tools: functionality, posture and muscles, pain in hand/finger, hand surface, handle characteristics, and aesthetics. These six factors primarily focus on user comfort. Some similarities with the results of this research include the factors of functionality. The results of this study are also different from those of Vaccari et al. [43], who formulated specific criteria for cooking technology for rural communities, namely, financial, health-related, environmental, and social in sub-Saharan Africa.

A design can be evaluated through four variables, namely, functional, usability, emotional, and aesthetic aspects [44]. Functionality entails meeting the fundamental design requirements, while usability pertains to the ease of use or operation. Aesthetics relates to the appearance of the product, while emotion encompasses the emotional benefits of a product in people's interactions. According to PCA results, these variables are integrated into the design factors. Functionality and aesthetics are linked to the second factor (functionality and economics). Usability and emotion are correlated with the third factor (user-friendly). The first factor (safety and error prevention) pertains to safety. The fourth, fifth, and sixth factors (physical workspace compatibility, low physical effort, and perceptible information) are associated with comfort, cognitive aspects, and the human factor.

3.4 Results of IPA

The results of the analysis of 197 respondents showed that the average values for the importance and performance of the AT machine are 4.3 ± 0.08 and 3.7 ± 0.14, respectively. According to the perception of users, there is still a gap between the performance and importance of the AT machine (Figure 6).

The measurement results of the perceived and expected use of AT machines are presented in an IPA, as shown in Figure 7, where each number indicates a factor code. In quadrant A, the users rate the AT design factor as very important but show low satisfaction. The AT design factors in quadrant B are rated as important and were satisfied with the existing performance. In quadrant C, the users are not satisfied with the existing performance and do not consider these factors important. The AT users in quadrant

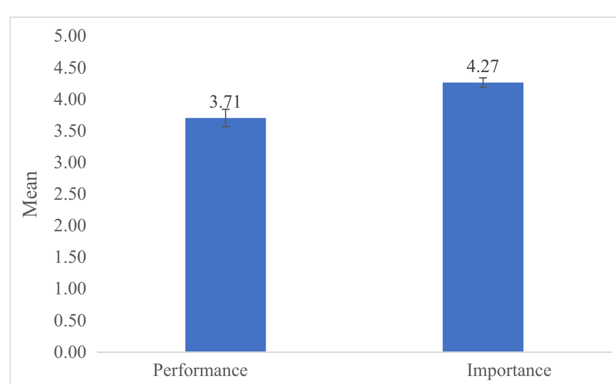

Figure 6: Mean value of importance and performance of the existing AT machines.

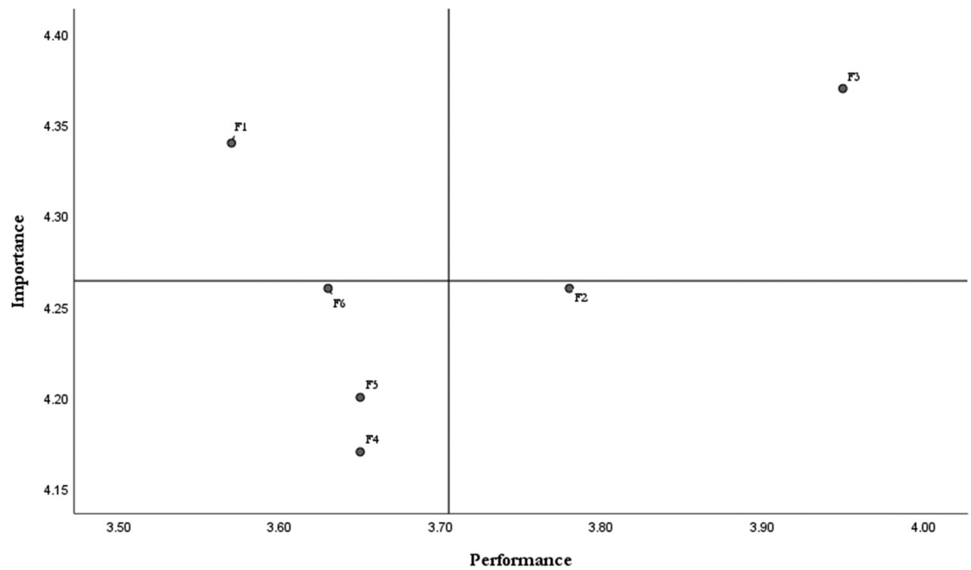

Figure 7: Importance-performance matrix.

D are satisfied with the given performance but rate these factors as less important.

Based on the outcomes of the IPA matrix, priority improvements for the design of AT machines should concentrate on one factor within quadrant A which is safety and error prevention. These attributes can be subdivided into two aspects. The first aspect involves the significance of AT machines with easily understandable usage guidelines and safety instructions. The second aspect pertains to the security of AT machines. Currently, many AT machines used in Indonesia lack manuals, primarily due to being manufactured by small to medium-scale workshops. Providing such guidelines aims to enable users to optimize machine functions and features, minimizing misuse and the risk of accidents.

Another significant priority for enhancing AT design pertains to machine safety. The AT machines were originally designed as simple manual machines to assist human labor, but several features and functions have been added later due to technological advancements and various needs. Not all AT machines in the community are equipped with security and safety features for users. Ensuring safety features is crucial for ongoing development and the application of active and passive safety features in the design of AT machines, both in the present and future.

In quadrant B, AT users assess crucial AT design indicators and express satisfaction with the provided performance, warranting maintenance. Indicators in this quadrant are regarded as important and are expected to bolster user contentment. This quadrant is deemed highly significant and gratifying. The design factors encompassed in quadrant B pertain to user-friendliness. Respondents find the AT machine relatively easy to operate, thereby emphasizing the need for its maintenance.

4 Conclusion

Design is one of the factors that must be considered in product development, including AT, to make it more ergonomic and effective. This research represents an initial step in the literature regarding design criteria for AT. Based on the factor analysis method, a total of 6 factors were produced with 41 design criteria. The results of the IPA matrix show that improvements to AT machines need to be prioritized in two aspects, including safety and user guide. For practitioners and designers, these results can assist in determining the design orientation of agricultural processing machines, taking into account human factors in addition to technical aspects, to enhance their effectiveness, especially for farmers and business actors. These results can also be of value to the industry, with the potential to enhance the competitiveness of agricultural product processing machines. Additionally, the research outcomes offer valuable insights to the government for the selection of agricultural processing machines to be disseminated to the public, thereby increasing their acceptance and sustainable utilization of AT. The research results have also been instrumental in developing a questionnaire for assessing and evaluating AT designs. Nevertheless, this research is subject to certain limitations as the sample of respondents is limited to Indonesian people. Future research could also explore methods for objectively evaluating the design of agricultural AT machines using experimental methods.

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