International Journal of Agricultural Technology 2023 Vol .19(4):1807-1824
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

# Knowledge, attitudes, and adoption process towards innovative agricultural food production with aquaponics for communities with limited spaces in urban Bangkok, Thailand

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Simakorn, S., Suwanmaneepong, S., Cavite, H. J. M. and Yomla, R. (2023). Knowledge, attitudes, and adoption process towards innovative agricultural food production with aquaponics for communities with limited spaces in urban Bangkok, Thailand. International Journal of Agricultural Technology 19(4):1807-1824.

**Abstract** The study found that household respondents have positive attitudes towards the Golden Apple Snail-Vegetable/Herb (GASVH) aquaponics innovation. Results implied that urban households were open to constant exploration of how the innovation would give better livelihood and income opportunities. Furthermore, the adoption acceptance survey revealed that household respondents generally have high-level ratings at each stage of the adoption process. This finding indicates respondents' positive knowledge and attitude toward an enhanced innovation adoption of GASVH aquaponics. It is recommended that GASVH aquaponics innovation be promoted particularly to urban households, as this can help to address food security and safety issues in urban areas. Urban families generally had high knowledge and positive attitudes towards technology which it is promising innovation for adoption.

**Keywords:** Agricultural innovation, Technology adoption, Aquaponics, Urban Thailand

## Introduction

Agri-food producers use innovation to boost productivity while better maintaining natural resources (Canavari *et al.*, 2022). Food safety is a critical issue that is gaining much attention today in agricultural innovations and supply chain management as it is linked between food and health (Ahangarkolaee and Gorton, 2021). It is also an essential aspect of food security, indicating that consumers have access to adequate and healthy food (Lim *et al.*, 2020), good nutrition, health, and well-being over the lifespan (Kaufman, 2015). With this, agri-food systems play a role in linking both security and food safety. This system ensures the safety and equal access to food under economic, social, and environmental challenges along with the increasing global population (Tan *et al.*, 2021). Aquaponics agricultural food system is one of the most sustainable

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food production practices recognized for its production efficiency, quality, and food safety (Zhang *et al.*, 2022).

Aquaponics technology is a synergistic method of food production between aquaculture and soilless cultivation under a closed water circulation system (Zhang *et al.*, 2022). This hybrid technology can increase productivity with less labor, land, and chemicals while reducing water consumption. Moreover, there is a strict control system, which is how it works if the soil is incomplete and lacks water, such as in urban areas (Department of Fisheries, 2019). Aquaponics system is a closed system technology designed to work semi-automatically, is space-saving, easy maintenance, and operationally convenient. Furthermore, this water-saving technology uses less labor and energy, does not use soil, chemical fertilizers, and pesticides, and can be applied in all suitable areas. This system can help address food security issues at the household level (Greenfeld *et al.*, 2020). Growing own vegetables and consuming them has several benefits, such as not requiring refrigeration, saving costs, and reducing wastage from buying more significant quantities than used (Office of the National Research Council, 2017).

The Golden Apple Snail-Vegetable/Herb (GASVH) aquaponics innovation is one innovative food production technique using aquaponics technology that produces food for households with limited space. This production system is designed to raise snails with crops in the recirculating closed-water system. Natural microorganisms will decompose the food waste, and the excretion of aquatic waste in the water filtration system provides nutrients that allow the plants to grow. GASVH aquaponics innovation has four major components: 1) the culture system, 2) the water treatment system with filter material in combination with vegetable growing, 3) the water control system, and 4) the greenhouse cover system to prevent vegetable pests (Figure 1). The products of the innovative agricultural food production by GASVH aquaponics innovation are golden apple snails and herbs grown according to consumer demand. Therefore, this system could provide households with an adequately accessible and nutritious source of high-protein food. In addition, snails' mussels are fresh, clean, tender, without water/mud odor, and can be consumed with confidence due to the knowledge of the source of production, which is currently popular with consumers in demand in the market. Accordingly, it is an alternative for sustainable income generation and additional household occupation.

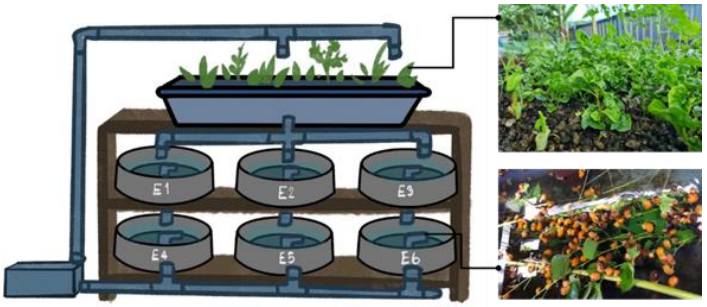


**Figure 1.** Golden Apple Snail-Vegetable/Herb (GASVH) aquaponics innovation

Studying innovation acceptance is a choice made when someone first identifies the innovation is required to turn innovation into action (Rogers, 1983). In this case, knowledge and attitudes about innovation influence the acceptance of innovation (Wajasuwan and Wongsaensukcharoen, 2022). Canavari, *et al.* (2022) emphasized that the factors affecting innovation adoption include: data transmission patterns, innovation characteristics, farm characteristics, and socio-economic and institutional factors. Eatmon *et al.* (2013) pointed out that opinion of innovation is a factor in the commercial acceptance of aquaponics innovations. Meanwhile, Greenfeld *et al.* (2020) explained that knowledge of aquaponics innovation is essential for those who embrace innovation. Brewer *et al.* (2021) also found that aquaponics practitioners focus on the profitability approach and environmentally friendly practices, including organic hydroponics production. Concurrently, much previous research by Liao *et al.* (2022), Chuang *et al.* (2020), and Seline *et al.* (2015) explored the role of knowledge, attitude, and adoption of innovation.

Controlling the food production system helps ensure that the production process and food are safe for consumption (Tan *et al.*, 2021). Food quality and safety management systems are ways to protect consumers from unsafe food (Asif *et al.*, 2018). In this case, agricultural food production with aquaponics is the appropriate technology to help address the issues of safe and secure foods at the household levels. This move also aligns with the Thai government's policy of ensuring consumers' access to safe and traceable foods, as mentioned in the National Strategy on Agriculture (2018-2037) by the National Economic and Social Development Council (2018). As this innovation concerns adopters' social and health dimensions, this study examines the urban households' characteristics, knowledge, attitude, and acceptance of GASVH aquaponics innovation.

This investigation uses the case of urban households in Chalong Krung Housing Community Zone 5, Nong Chok District, Bangkok, grounded by the

idea that agricultural food systems suitable for urban farming (or areas with limited space) can be quickly done in the backyard under the aquaponic system. This innovation ensures safety throughout the food chain, from raw material production to food processing, delivery, and preparation (Tan *et al.*, 2021). Therefore, the objectives were to assess the likelihood of acceptance of this agricultural innovation in households with limited space in the Bangkok metropolitan area, to provide information and guidelines to promote and expand the innovative agricultural food production with the acquaponics system.

## Materials and methods

### *Study area and participants*

The data collection was conducted in Chalong Krung Housing Community Zone 5, Nong Chok District, an urban community with limited space within a radius of 30 km in Bangkok, Thailand (Figure 2). This area is also close to the source of innovation and model households utilizing innovations. Moreover, information can be easily accessed by viewing innovative prototypes, including in urban areas where the population has limited space (Naha, 2022). The participants in this study were urban households. Most households do not have enough space to produce food for consumption. Furthermore, they still rely on buying food from street stalls and restaurants along the pavement, which is among the causes of health problems (Alimi, 2016, Rane, 2011).

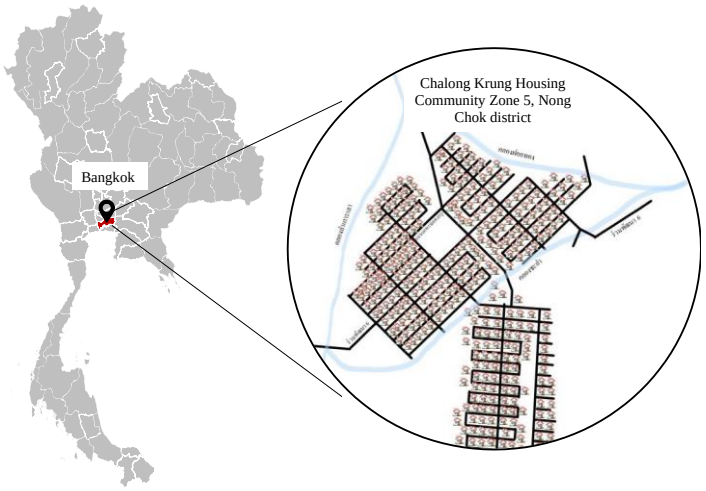


**Figure 2.** Map of Thailand showing the study area Chalong Krung Housing Community Zone 5, Nong Chok district, Bangkok

### *Data collection*

Data were gathered through training and face-to-face surveys with urban household respondents. Initially, training, and academic dissemination were conducted in the urban community on the overview, usefulness, and importance of GASVH aquaponics system innovation. Then, training with demonstrations was organized to expound on how to use the technology, disseminate and improve the households' level of awareness and develop their skills in using the innovation. Ultimately, the survey data were collected from 60 training participants using a structured questionnaire. Data gathered include household members' socio-economic data, knowledge, attitude, and adoption innovation acceptance toward GASVH aquaponics innovation. The data collection procedure is shown in Figure 3.


**Figure 3.** Training and data collection activities with household members of the study area

### *Data analysis*

Interview data were encoded and analyzed using Statistical Package for Social Sciences (SPSS) program. Descriptive statistics in terms of means and percentages were used to describe consumers' demographic profiles. In addition, means and standard deviation were computed for knowledge, attitude, and adoption acceptance factors (McHugh, 2013, Zhou *et al.*, 2015). Measurement items for knowledge about GASVH aquaponics innovation was evaluated by respondents using point scoring. In this case, 1 point was given to every correct item (true), and 0 point for every incorrect item (false). Respondents' knowledge was classified into three levels based on score percentage: low (less than 60%), moderate (60% to 80%), and high (more than 80%) (Bloom and Krathwohl, 1956). Meanwhile, attitude was measured using five-point Likert scale (i.e., 1 = strongly disagree, 2 = disagree, 3 = neither

agree nor disagree, 4 = agree, and 5 = strongly agree) (Likert, 1932). Lastly, the respondents' adoption level was assessed in terms of the their awareness, interest, evaluation, trial, and adoption of the GASVH aquaponics innovation (Fawole and Aderinoye-Abdulwahab, 2021).

## Results

### *Socio-demographic profile of respondents*

Community household respondents' demographic profiles were summarized and presented in Table 1. The results showed that most respondents were female (61.7%), and the majority were between 51 and 70 (33.3%). As with education level, the majority of the household respondents finished primary school level (71.7%). The analysis also indicated that most respondents were housekeepers (51.7%), and most had a monthly income lower than 15,000 THB (83.3%). The highest proportion of the respondents (51.7%) lives in a three-to-four-person household. Additional information about the respondents includes their training attendance on golden apple snail raising. The majority of the respondents (90%) revealed that they have never attended such training before and that their sources of information about the golden apple snail aquaponics innovation are their personal experience (29%) and YouTube instructional videos (12%).

**Table 1.** Socio-demographic profile of household respondents (n=60)

| Socio-demographic profile | Frequency | % |
|---|---|---|
| **Gender** | | |
| Male | 23 | 39.3 |
| Female | 37 | 61.7 |
| **Age (years)** ($\bar{x}$ = 54.95, max = 79, min = 21) | | |
| Below 40 | 7 | 11.7 |
| 41 – 50 | 11 | 18.3 |
| 51 – 60 | 20 | 33.3 |
| 61 – 70 | 20 | 33.3 |
| More than 70 | 2 | 3.3 |
| **Education** | | |
| Primary school | 43 | 71.7 |
| Junior high school | 4 | 6.7 |
| High school/ vocational | 3 | 5.0 |
| Diploma/ high vocational certificate | 1 | 1.7 |
| Bachelor's degree | 8 | 13.3 |
| Postgraduate | 1 | 1.7 |

**Table 1.** (Con.)

| Socio-demographic profile | Frequency | % |
|---|---|---|
| **Occupation** | | |
| Student | 2 | 3.3 |
| Business Owner/ Freelancer | 8 | 13.3 |
| Private company employees | 2 | 3.3 |
| Government officer | 1 | 1.7 |
| Housekeeper | 31 | 51.7 |
| General employee | 2 | 3.3 |
| Street vendor | 5 | 8.3 |
| Others | 9 | 15.0 |
| **Monthly income** | | |
| Lower than 15,000 THB | 50 | 83.3 |
| 15,001 – 25,000 THB | 5 | 8.3 |
| 25,001 – 35,000 THB | 2 | 3.3 |
| 45,001 – 55,000 THB | 1 | 1.7 |
| More than 55,000 THB | 2 | 3.3 |
| **Household member** | | |
| 1 – 2 persons | 12 | 20.0 |
| 3 – 4 persons | 31 | 51.7 |
| 5 – 6 persons | 10 | 16.7 |
| 7 – 8 persons | 6 | 10.0 |
| 9 – 10 persons | 1 | 1.7 |
| **Training with golden apple snail raising** | | |
| Attended | 6 | 10.0 |
| Never attended | 54 | 90.0 |
| **Source of information on GASVH aquaponics innovation** | | |
| Facebook | 5 | 8.3 |
| YouTube | 12 | 20.0 |
| Training programs | 3 | 5.0 |
| TV | 3 | 5.0 |
| Newspaper | 1 | 1.7 |
| Internet | 3 | 5.0 |
| Other (Friend/ Community leader) | 4 | 6.7 |
| Own personal experience | 29 | 48.3 |

### *Knowledge of the GASVH aquaponics innovation*

Knowledge analysis of respondents toward the GASVH aquaponics innovation was done using 11 key questions. Results revealed that respondents had an average knowledge score of 8.07 (Figure 4). In addition, the analysis showed that most of the respondents (51.70%) had a reasonably good knowledge of golden apple snail cultivation, while 40% had a high knowledge level. Meanwhile, only 8.3% of the household respondents demonstrated the slightest understanding of the GASVH aquaponics innovation.

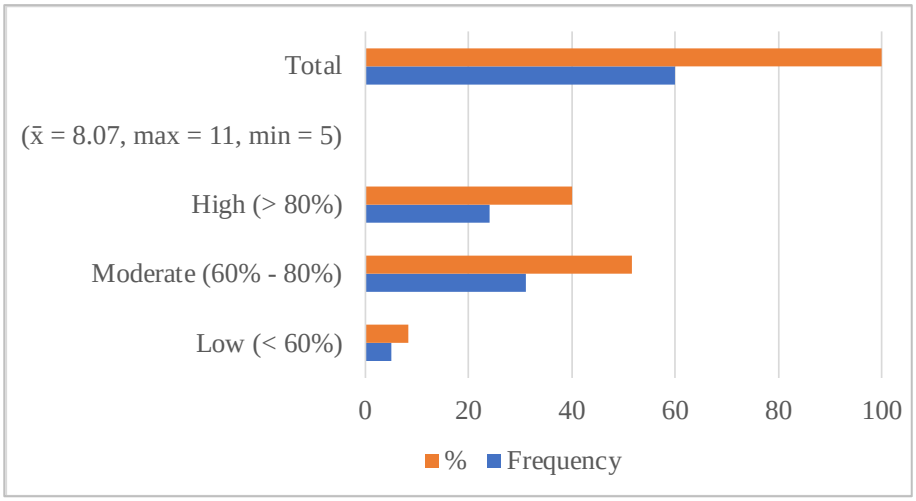


**Figure 4.** Knowledge of the GASVH aquaponics innovation

Result showed the respondents' knowledge of the innovation in each of the four aspects – innovation description, innovation objective, knowledge and understanding, and form and methods of raising. Respondents obtained the most correct answers in the 'innovation's objective' aspect (90.50%), followed by the knowledge and understanding aspect (67.80%) (Table 2). However, among the four aspects, the respondents have the least knowledge of the innovation's form and method of raising (61.50%).

The specific GASVH aquaponics innovation's knowledge items in each aspect revealed that respondents had varied levels of understanding. For instance, in the innovation description aspect, participants moderately understand all items. Most of their understanding that the golden apple snail aquaponics innovation was raising snails and growing plants without soil (70%). Meanwhile, in the innovation's objective aspect, participants had a high understanding of all items. The most correct answers were obtained from the item: making food available for household consumption (93%). As for the knowledge and understanding aspect, respondents' knowledge ranged from low to moderate to high. Most respondents understand that the innovation allows for changing types of aquatic animals and vegetables (85%). As for the last aspect, form, and methods of raising, respondents have low and moderate understanding. The respondents did not understand the differences between the golden apple snail culture system and the conventional snail culture system (50%).

**Table 2.** Knowledge of the GASVH aquaponics innovation by aspect

| Item | Correct answer | | Knowledge Level |
|---|---|---|---|
| | Frequency | % | |
| **I. Innovation description** | **38.66** | **64.40** | **Moderate** |
| 1. The aquaponics system combines aquaculture and plants without soil. | 38.00 | 63.30 | Moderate |
| 2. The golden apple snail aquaponics innovation is for raising snails and growing plants without soil. | 42.00 | 70.00 | Moderate |
| 3. "Growing plants without soil" comes from the word "hydroponics" and is the cultivation of plants without plant material. | 36.00 | 60.00 | Moderate |
| **II. Innovation's objective** | **54.33** | **90.50** | **High** |
| 4. It makes food available for household consumption. | 56.00 | 93.30 | High |
| 5. It is a system that can be adapted to household areas. | 54.00 | 90.00 | High |
| 6. It makes nutritious food source without toxic residues. | 53.00 | 88.30 | High |
| **III. Understanding of innovation** | **40.66** | **67.80** | **Moderate** |
| 7. Various wastes will accumulate on the filter media without being naturally decomposed. | 46.00 | 76.70 | Moderate |
| 8. Able to be done without knowledge and experience. | 25.00 | 41.70 | Low |
| 9. Able to be changed the types of aquatic animals and vegetables as needed. | 51.00 | 85.00 | High |
| **IV. Form and methods of raising** | **37.00** | **61.50** | **Moderate** |
| 10. There is no difference between the golden apple snail culture system and the conventional snail culture system. | 30.00 | 50.00 | Low |
| 11. GASVH aquaponics innovation has four parts: 1) culture system, 2) water treatment system with filter material in combination with vegetable growing, 3) water control system, and 4) greenhouse cover to prevent vegetable pests | 44.00 | 73.30 | Moderate |

### *Attitude towards GASVH aquaponics innovation*

Household respondents' attitudes towards GASVH aquaponics innovation were assessed and presented in Figure 5. Results revealed that the

majority of the respondents had positive attitudes towards GASVH aquaponics innovation. Most of them strongly agreed (45%) and agreed (45%) that raising snails using the GASVH aquaponics innovation system is a good idea. Adding to that, the respondents also revealed the benefits of this new innovation system and had positive outlook on applying this technology based on their capabilities earned from trainings and demonstrations. Only 10% of the respondents had neutral attitudes on this aspect. Meanwhile, it showed the respondents' attitudes towards GASVH aquaponics innovation by major aspect (Table 3). Household respondents had the highest attitude towards the benefits from golden apple snail aquaponics innovation ($\bar{x}$ = 4.47, SD = 0.569), followed by the innovation's compatibility ($\bar{x}$ = 4.42, SD = 0.658) and complexity ($\bar{x}$ = 4.42, SD = 0.658).

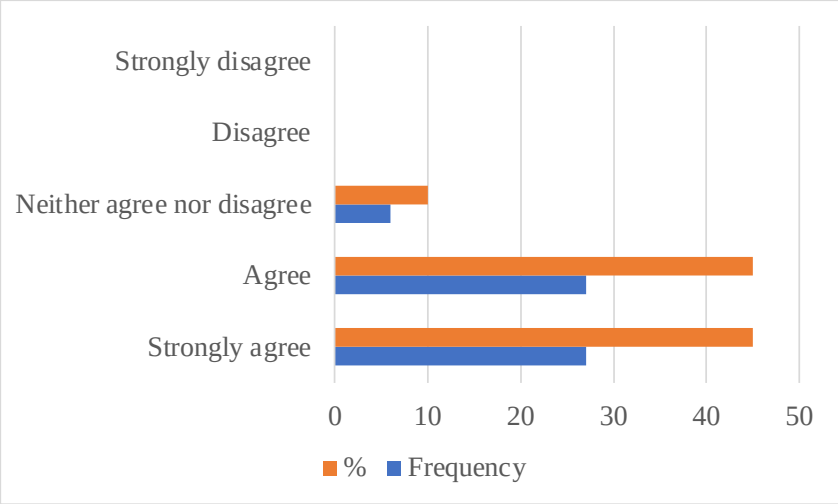


**Figure 5.** Attitude towards GASVH aquaponics innovation

**Table 3.** Attitudes towards GASVH aquaponics innovation by major aspect

| | Item | Mean ($\bar{x}$) | S.D. | Interpretation |
|---|---|---|---|---|
| I. | Benefits from the GASVH aquaponics innovation | 4.47 | .569 | Agree |
| II. | Ease of raising snails with the GASVH aquaponics innovation | 4.38 | .628 | Agree |
| III. | Ability to control the GASVH aquaponics innovation | 4.26 | .799 | Agree |
| IV. | Social networks influenced the decision to use GASVH aquaponics innovation | 3.95 | .865 | Agree |
| V. | Compatibility | 4.42 | .658 | Agree |
| VI. | Complexity | 4.42 | .585 | Agree |

The details of household respondents' attitude towards the GASVH aquaponics innovation is shown in Table 4. The technology's benefits, the respondents strongly agreed with the idea that such innovation helped household cooking more productive, convenient, and fast ($\bar{x}$ = 4.62, SD = 0.555), and the technology made safety food for household consumption ($\bar{x}$ = 4.67, SD = 0.542). The ease of technology, respondents strongly agreed that the innovation can be done in a limited space ($\bar{x}$ = 4.58, SD = 0.671) and had a system that allowed the used materials that suited to the area ($\bar{x}$ = 4.53, SD = 0.650). The ability to control the aquaponics innovation and social networks influencing the decision to use technology, all items were agreed upon by the respondents. Results revealed that respondents had the interest to explore the new innovation ($\bar{x}$ = 4.30, SD = 0.926) and that training participation had influenced them to use the technology ($\bar{x}$ = 4.27, SD = 0.899). The compatibility and complexity of the aquaponics innovation, most items were agreed upon by the respondents. They viewed the technology as something that ensured enough safe food for family consumption ($\bar{x}$ = 4.50, SD = 0.834) and strongly agreed that raising snails in the GASVH aquaponics innovation was easy and management was not difficult ($\bar{x}$ = 4.52, SD = 6.51).

**Table 4.** Attitudes toward GASVH aquaponics innovation in each aspect

| Item | Mean ($\bar{x}$) | S.D. | Interpretation |
|---|---|---|---|
| **I. Benefits from the GASVH aquaponics innovation** | | | |
| 1. It helps household cooking be more productive, convenient, and fast. | 4.62 | .555 | Strongly agree |
| 2. It makes food safe for household consumption. | 4.67 | .542 | Strongly agree |
| 3. It can be a source of additional income for households. | 4.43 | .927 | Agree |
| 4. It can reduce the cost of purchasing food for the household. | 4.40 | .827 | Agree |
| 5. It involves extra activities that are beneficial (relaxing, exercising). | 4.45 | .946 | Agree |
| 6. Able to trace the source of food to eat. | 4.27 | .880 | Agree |
| **II. Ease of raising snails with the GASVH aquaponics innovation** | | | |
| 7. The technology can easily be followed based on training instructions. | 4.17 | .785 | Agree |
| 8. The innovation is suitable for household consumption support. | 4.25 | .895 | Agree |
| 9. The innovation can be done in a limited space. | 4.58 | .671 | Strongly agree |
| 10. The innovation has a system that allows material use that suit the area. | 4.53 | .650 | Strongly agree |

**Table 4.** (Con.)

| | | | |
|---|---|---|---|
| **III. Ability to control the GASVH aquaponics innovation** | | | |
| 11. There is always interest in experimenting with new things, so there is no problem in raising golden apple snails with GASVH, which is an aquaponics innovation. | 4.30 | .926 | Agree |
| 12. Able to understand the raising system and the circulation of the water system very well. | 4.20 | .917 | Agree |
| 13. The pattern and plants grown in the GASVH aquaponics innovation can be adjusted according to the habitat area. | 4.30 | .962 | Agree |
| **IV. Social networks influenced the decision to use GASVH aquaponics innovation** | | | |
| 14. Neighbors/colleagues recommend the technology. | 4.05 | 1.11 | Agree |
| 15. Family members recommend the technology. | 3.73 | 1.17 | Agree |
| 16. Influence after attending the training about the technology. | 4.27 | .899 | Agree |
| 17. Influence after observing others use the technology. | 3.78 | 1.09 | Agree |
| **V. Compatibility** | | | |
| 18. It is a modern snail raising system compatible with today's society. | 4.32 | .930 | Agree |
| 19. It ensures that there is enough food safe for family consumption. | 4.50 | .834 | Agree |
| 20. It is a snail-raising system suitable for living in the modern era (e.g., the Covid-19 pandemic). | 4.47 | .700 | Agree |
| **VI. Complexity** | | | |
| 21. The process of raising snails in the GASVH aquaponics innovation is not complicated. | 4.40 | .643 | Agree |
| 22. Raising snails in the GASVH aquaponics innovation is easy, and management is not difficult. | 4.52 | .651 | Strongly agree |
| 23. Snail raising in a closed circulating water system does not require frequent water changes. | 4.37 | .938 | Agree |

### *Adoption of GASVH aquaponics innovation*

Results showed that the respondents' ratings at each stage of the adoption process – awareness, interest, evaluation, trial, and adoption (Figure 6). It revealed that respondents generally had high-level ratings at each stage. The overall mean was computed at 4.26. Among the adoption stages, awareness had the highest rating ($\bar{x}$ = 4.39, SD = 0.575), and followed by evaluation ($\bar{x}$ = 4.33, SD = 0.540).

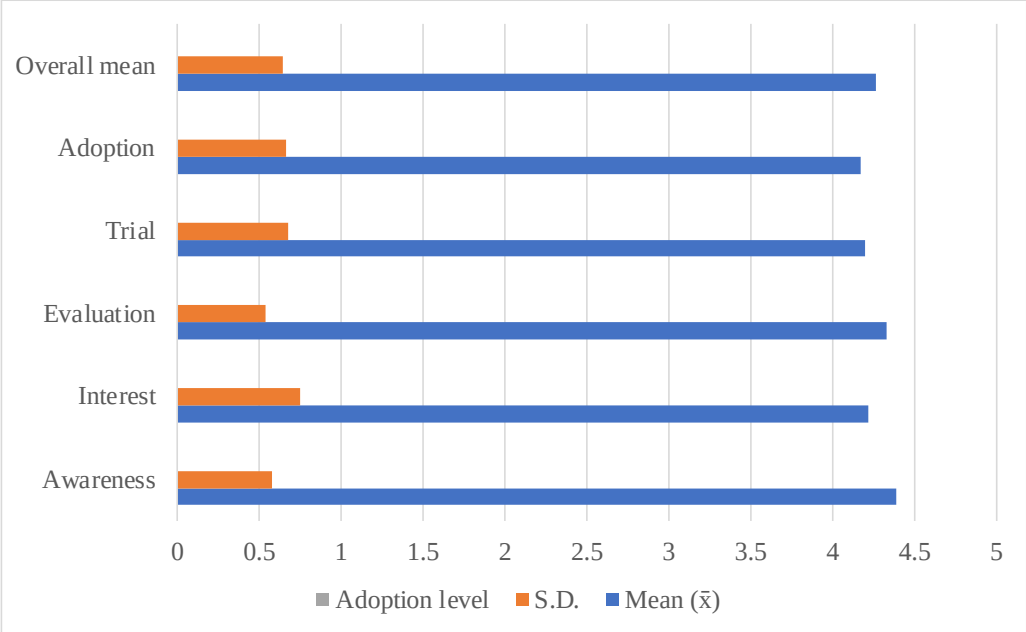


**Figure 6.** Stages of the adoption process of the GASVH aquaponics innovation

Result showed the details of the acceptance rating of the respondents at each stage in the adoption process (Table 5). In the awareness stage, respondents gave very high ratings to the idea that type of innovation can be carried out in a limited space ($\bar{x}$ = 4.53, SD = 0.676) and with many types of vegetables that can be grown together ($\bar{x}$ = 4.50, SD = 0.873). The interest stage, all three items obtained high ratings, signifying high respondents' interest in GASVH aquaponics innovation. Meanwhile, for the evaluation phase, household respondents gave a high rating to the idea that snails should be raised with GASVH aquaponics innovation to generate additional income for the household ($\bar{x}$ = 4.47, SD = 0.700). Finally, the last two stages were trial and adoption, which received high ratings from the respondents. In the trial phase, respondents were delighted with using the GASVH aquaponics innovation to raise snails in some areas of their houses ($\bar{x}$ = 4.35, SD = 0.799). Furthermore, in the adoption phase, participants showed high intention to use the technology and even disseminate the information on GASVH aquaponics innovation to other interested parties ($\bar{x}$ = 4.42, SD = 0.743).

**Table 5.** Acceptance of the GASVH aquaponics innovation by the participants based on the adoption stage

| Stages of the adoption process | Mean | S.D. | Adoption level |
|---|---|---|---|
| **Awareness** | | | |
| 1. Snail cultivation in the GASVH aquaponics innovation can be carried out in a limited space. | 4.53 | .676 | Very high |
| 2. The GASVH aquaponics innovation is similar to the hydroponics system. | 4.28 | .885 | High |
| 3. In the GASVH aquaponics innovation, many types of vegetables can be grown together. | 4.50 | .873 | Very high |
| 4. Well-aware of how to grow vegetables in the GASVH aquaponics innovation. | 4.25 | .795 | High |
| **Interest** | | | |
| 5. I am interested to see the GASVH aquaponics innovation prototype area. | 4.38 | .885 | High |
| 6. Interested in experimenting with the GASVH aquaponics innovation. | 4.02 | .965 | High |
| 7. Interested in finding out more about GASVH aquaponics innovation. | 4.28 | .940 | High |
| **Evaluation** | | | |
| 8. Snail raising with the GASVH aquaponics innovation is useful in household food production. | 4.42 | .696 | High |
| 9. Has the ability to raise snails with the GASVH aquaponics innovation. | 4.10 | .775 | High |
| 10. Snails should be raised with the GASVH aquaponics innovation to generate additional income for the household. | 4.47 | .700 | High |
| 11. Raising snails with the GASVH aquaponics innovation is simple and adaptable to limited space conditions. | 4.43 | .767 | High |
| 12. Raising snails with the GASVH aquaponics innovation requires a lot of knowledge and skill. | 4.27 | .756 | High |
| **Trial** | | | |
| 13. Learning to grow snails with the GASVH aquaponics innovation as a household food source. | 4.28 | .761 | High |
| 14. Using the GASVH aquaponics innovation to raise snails in some areas of the house. | 4.35 | .799 | High |
| 15. Intending to implement and design a raising system to suit the area. | 4.07 | .841 | High |
| 16. Studying and developing snail raising with the GASVH aquaponics innovation continuously. | 4.13 | .769 | High |
| 17. Intending to expand snail raising with the GASVH aquaponics innovation to generate income for households. | 4.17 | .924 | High |
| **Adoption** | | | |
| 18. Will raise snail with the GASVH aquaponics innovation to provide food/ additional income to the household. | 4.25 | .876 | High |
| 19. Thinking about raising snails with the GASVH aquaponics innovation even though I do not have the expertise. | 3.92 | .907 | High |
| 20. Even if there are problems in raising snails in the GASVH aquaponics innovation, I will adjust and adapt to it. | 4.10 | .817 | High |
| 21. I will continue to disseminate the GASVH aquaponics innovation information to other interested parties. | 4.42 | .743 | High |

## Discussion

This study examined the urban households' characteristics, knowledge, attitude, and adoption of GASVH aquaponics innovation. This is anchored on the understanding that adoption of a particular innovation concerns the adopters' social and health dimensions (Boehlje and Bröring, 2011). The findings showed that most respondents had a moderate (51.70%) and high (40%) knowledge about GASVH aquaponics innovation. This indicates that this aquaponics innovation is already familiar among urban households. Awareness of the innovation is an important aspect to consider in promoting the widespread adoption of an innovation (Gonzalvo *et al.*, 2020). Innovation awareness helps an adopter build a culture of continuous learning and adapt to associated challenges in using the innovation (Kassem *et al.*, 2021). In a study by Kılıç *et al.* (2020), innovation awareness helps adopters distinguish the technical perspective differences between conventional and good agricultural practices (Llones and Suwanmaneepong, 2021). Moreover, this current study reveals that respondents are well aware of the innovation objective and have a fair understanding of using the technology. This finding is consistent with Oo (2020) who found that adopters' awareness is an important factor in innovation adoption. Understanding the objective of innovation helps adopters better understand how to create more value in their daily life and creates a more efficient lifestyle (Lee and Trimi, 2018). This is consistent with the idea of GASVH aquaponics innovation, as it is developed to enable households in rural areas to produce safer and healthier foods that are safe for their consumption.

The study found that household respondents have positive attitudes towards the GASVH aquaponics innovation. This finding indicates that urban households are open to constant exploration of how this innovation would give better opportunities in their daily life (Anand *et al.*, 2021). This also indicates that respondents see the GASVH aquaponics innovation as beneficial in improving household productivity and reducing costs. Similar findings were revealed from the study of Edison and Geissler (2003), showing that certain beneficial factors contribute to the resistance of new technologies. More specifically, from this study, evidence has been found that respondents have the highest attitude towards the benefits and compatibility of this aquaponics innovation (Llones *et al.*, 2022). Such findings indicate that GASVH aquaponics innovation is something households see as convenient to use and suitable in their present situation. Innovation convenience is essential for the adopter experience (Dike, 2021). It is a critical factor that determines whether adopters will continue to use the innovation or not (Anand, *et al.*, 2021).

The adoption acceptance survey revealed that household respondents generally have high-level ratings at each stage of the adoption process. This

finding indicates that respondents' positive knowledge and attitude enhance innovation adoption towards GASVH aquaponics innovation. Innovation adoption is a step-by-step process and is usually influenced by the adopter's behavior and technology characteristics (Waarts *et al.*, 2002). This study finds evidence that household respondents were already aware of the GASVH aquaponics innovation, interested in the technology, and willing to evaluate, try and adopt the said technology. Moreover, this study's results also revealed that awareness and evaluation have the highest ratings among the adoption stages. Awareness is a vital tool for innovation adoption (Mannan and Haleem, 2017), and evaluating the innovation allows the adopter to strengthen existing knowledge and efficiently assess its impact (de Abreu *et al.*, 2008).

As a recommendation, it is proposed to concern government agencies that this GASVH aquaponics innovation is promoted particularly to urban households to address food security and safety issues in urban areas. The urban families generally had high knowledge and positive attitudes towards technology. Most importantly, it is recommended to conduct further training for using this technology to strengthen people's knowledge and awareness. This may encourage other urban households to adopt and promote widespread of this promising innovation.

## Acknowledgements

The authors want to acknowledge the household respondents at Chalong Krung Housing Community Zone 5, Nong Chok District, Bangkok, Thailand. This study was conducted with Human Ethics Study code EC-KMITL_65_126. This project was supported by the KMITL Research and Innovation Services (KRIS) Master's degree research fund for the fiscal year 2022, King Mongkut's Institute of Technology, Ladkrabang, Bangkok, Thailand.

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(Received: 23 September 2022, accepted: 27 May 2023)