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INFORMATION ACCESSIBILITY AND RESOURCE USAGE BY AQUAPONIC STAKEHOLDERS

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ABSTRACT

Aquaponics has gained considerable attention in the past several years, bringing many new stakeholders into the fold. As with any new industry there are unknowns making newcomers susceptible to misinformation. It is critical to provide high quality information on relevant topics in appropriate formats to promote success within the aquaponics industry. This study assesses usage of various informational resource outlets and accessibility of quality information in nine competency areas by different stakeholder groups. Quality information was perceived as '*moderately accessible*' in general, although this varied by stakeholder group and topic. Information on marketing food products and financial record keeping generally had the lowest accessibility ratings overall. The most commonly utilized information sources overall were internet and videos, books and library, and classes and workshops. The most commonly desired information resources overall were other aquaponic growers, Extension agents, classes/workshops, Extension publications, and manufacturers/suppliers. The three most unused resources across all groups were friends and family, consultants, and social media. This study provides a guide for prioritizing efforts to inform and support aquaponic growers for content providers like academics, consultants, public agencies, and non-government organizations.

INTRODUCTION

Aquaponics is a growing field of agriculture that integrates fish and plant culture to promote food production, self-sufficiency, environmental sustainability, community enhancement, and profit (Love et al., 2014). The aquaponics industry is currently in a growth phase, with interest levels soaring and new production systems being developed around the world (Love et al., 2014). However, the initial excitement and hype has diminished due to a number of failures experienced by early adopters due in part to lack of access to quality information in critical areas (Linden and Fenn, 2003; Junge et al., 2017; König et al., 2018; Greenfeld et al., 2019; Turnsek et al., 2020). The cumulative effect of these failures is a distrust amongst growers, investors, and lending agencies resulting in constricted growth of the aquaponics industry.

With relatively few quality training opportunities in aquaponics it is important to provide relevant, timely, and credible educational resources to improve grower success (Genello et al., 2015; Greenfeld et al., 2019). This study surveyed aquaponic industry participants, namely hobbyists, producers and educators to 1) evaluate perceived accessibility of quality information in nine core competency areas, 2) evaluate usage of informational resources, and 3) provide recommendations for resource development. This assessment provides guidance for educational resource providers in support of the aquaponic industry.

METHODS

The authors developed an online survey instrument that combined previous industry surveys (Love et al. 2014; Villarroel et al., 2016) and researcher-developed questions, with concepts recommended by Dillman (2007) and Fowler (2009). The question clarity and face validity were verified externally through the Aquaponics Association membership prior to final approval (IRB Protocol No: 19-544 EX 1912). Survey participants were solicited from social media, Extension contacts, and professional associations with a focus on aquaponics. The 'snowball' advertising method was used to expand the audience captured in the survey results by encouraging respondents to share the survey among their peers (Browne, 2005; Baltar and Brunet, 2012; Love et al., 2014). However, this method prevented the calculation of a reliable response rate because the number of potential respondents is unknow. This study represents a portion of a larger aquaponics industry survey conducted by Pattillo (2021) from December 2019 to June 2020. The full survey is available from Pattillo (2021), but the focus of the present study is the usage of certain information resources and the accessibility of content in core areas.

CORE COMPETENCIES

Competency areas assessed were system design (SD), system construction (SC), system maintenance (SM), water chemistry (WC), fish health-disease (FHD), plant pest-disease-nutrient deficiencies (PPD), financial record keeping (FRK), marketing food products (MFP) and food safety (FS). Accessibility of quality information (A) in the nine core competency areas were rated as 1 = *not*, 2 = *slightly*, 3 = *moderately*, 4 = *very*, and 5 = *extremely* accessible. The composite accessibility score was calculated as the sum of 'A' ratings for respondents that rated all nine competency areas. The composite score provides an index of the respondent's overall perceptions of aquaponic content accessibility, which was compared statistically among groups.

INFORMATIONAL RESOURCE USAGE

Survey respondents were presented with a list of informational resources and asked to sort them into one of three categories: 'currently use' (used), 'want to use' (desired), and 'do not use' (unused). Each information source could only be sorted into one category, and therefore were mutually exclusive. The frequency and proportion of respondent selections are reported by use category, resource type, and stakeholder group.

STATISTICAL ANALYSIS

Survey response data was compiled in Qualtrics XM (Provo, UT, USA) and analyzed in SPSS Statistic 26 (IBM, Armonk, NY, USA) and Excel (Microsoft 360, Redmond, WA, USA). After removing outliers and illogical responses, data characteristics were generalized using mean ± standard deviation (SD), median (M) and inter-quartile range (IQR), and proportions (e.g. percentage). One-way Analysis of Variance (ANOVA) with Tukey's Post-Hoc test for pairwise comparisons ($\alpha = 0.05$) detected differences between group means. Where necessary, data was transformed with the natural logarithm function to meet normality assumptions. Ordinal data was analyzed using the nonparametric Spearman's correlation (ρ) to measure the strength (Evans, 1996) and nature of relationships between sets of variables with Bonferroni adjustment for multiple comparisons ($\alpha = 0.05/n$) to reduce the risk of Type I error. Cronbach's alpha (0.893) was calculated for Likert scaled accessibility data, indicating the responses were reliable (Habidin et al., 2015).

RESULTS

DEMOGRAPHICS AND BACKGROUND

Out of 378 respondents, 28% were hobbyists ($n = 105$), 41% were producers ($n = 156$), and 31% were educators ($n = 117$). The typical respondent was white/Caucasian (75%), male (80%), American (82%), 55 to 64 years of age (32%), and employed full time (62%), although many hobbyists (35%) and producers (18%) were retirees. Median years of aquaponic experience was 3 to 5 years for hobbyists, and 3 to 10 years for producers and educators. Eighty percent of respondents ($N = 298$) had some sort of training, with informal training (64%) being the most common overall, although 41% had work experience, and 24% had formal training. More detailed participant background information can be found in Pattillo (2021). The average number of training types selected (excluding non-trained respondents) was 1.3 ± 0.5 for hobbyists, which was significantly lower ($p = 0.001$) than producers (1.8 ± 0.7), but not different than educators (1.5 ± 0.7). Overall, the number of training sources used was weakly positively correlated (Evans, 1996) with years of aquaponic experience ($\rho = 0.342$, $p < 0.001$).

Overall, the most commonly selected interest areas were environmental sustainability and healthy food. Self-sufficiency, healthy food, fish, and education were also common interests, although this varied by stakeholder group. Of the 321 respondents, 57%, 21%, 15%, and 7% were in the operational, planning, researching, and construction phases, respectively. Overall, respondent progression through developmental stages (e.g. researching < planning < facility constructed < facility in operation) was significantly correlated with the number of years of experience ($\rho = 0.370$, $p < 0.001$), number of information sources used ($\rho = 0.123$, $p = 0.041$), and number of training sources used ($\rho = 0.172$, $p = 0.009$). The strength of these correlations varied by stakeholder group (Table 1).

Table 1. Spearman correlation coefficients between experience, training, and information resource utilization.

Hobbyist		1	2	3	4
1	Years of Aquaponic Experience	--			
2	Number of Training Sources Used	**.415****†	--		
3	Number of Info Sources Used	**.357****	**.338***	--	
4	Stage of Development	**.384****	.016	.105	--
5	Composite Accessibility Score	.213	.052	.219	.082
Producer		1	2	3	4
1	Years of Aquaponic Experience	--			

2	Number of Training Sources Used	.139	--		
3	Number of Info Sources Used	.108	**.245***	--	
4	Stage of Development	**.467****	.105	.152	--
5	Composite Accessibility Score	.127	.019	.084	-.065
Educator		1	2	3	4
1	Years of Aquaponic Experience	--			
2	Number of Training Sources Used	**.396****	--		
3	Number of Info Sources Used	**.353****	**.302***	--	
4	Stage of Development	**.282****	**.311***	.111	--
5	Composite Accessibility Score	.054	.125	.016	.185

***p* ≤ 0.05, ****p* ≤ 0.005;** Bonferroni adjustment for multiple correlations to minimize risk of Type I error. (α = 0.05/ = 0.005)

† Correlation strengths defined as very weak (0.0 < ρ < 0.19), weak (0.2 < ρ < 0.39), moderate (0.4 < ρ < 0.59), strong (0.6 < ρ < 0.79), or very strong (0.8 < ρ < 1.0) (Evans, 1996).

CORE COMPETENCY INFORMATION ACCESSIBILITY

The median information accessibility (A) rating was generally '*moderately accessible*' (A = 3) (Figure 1). Hobbyists rated SD and SC highest (A = 4) and MFP lowest (A = 2). Producers rated all accessibility of aquaponic information topics similarly. Educators rated accessibility highest for WC (A = 4), and all others as moderate (A = 3). Composite accessibility scores were not significantly different among stakeholder groups ($p > 0.121$), with means ranging from 27.1 to 29.4 out of a potential score of 45. Overall, composite accessibility score was very weakly correlated (Evans, 1996)) with years of experience ($\rho = 0.173$, $p = 0.002$) and number of information resources used ($\rho = 0.148$, $p = 0.015$); however, this correlation was not detected by stakeholder group (Table 1).

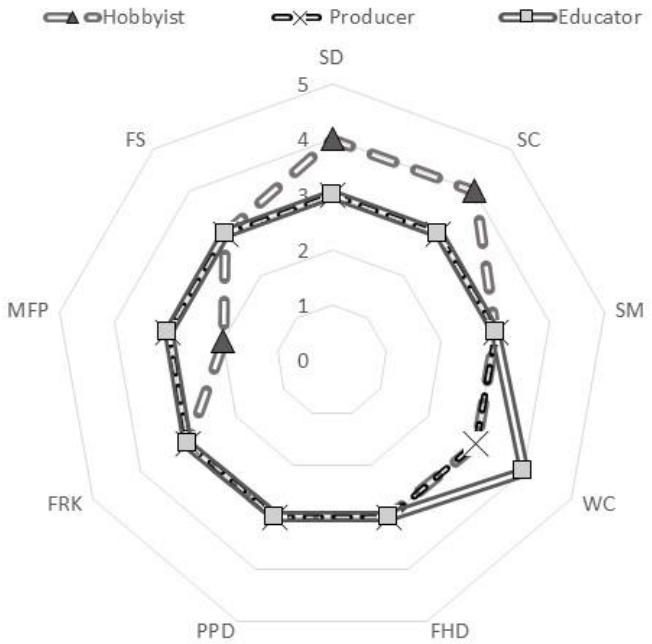

Figure 1. Median accessibility of quality information ratings in nine core competency areas for aquaponic hobbyists, producers, and educators. Accessibility ratings based on a Likert scale where 1 = *not*, 2 = *slightly* 3 = *moderately*, 4 = *very*, and 5 = *extremely* accessible. Core competencies include System Design (SD), System Construction (SC), System Maintenance (SM), Water Chemistry (WC), Fish Health & Disease (FHD), Plant Pest, Disease, and Nutrient Deficiencies (PPD), Financial Record Keeping (FRK), Marketing Food Products (MFP), Food Safety (FS)

INFORMATION RESOURCE USAGE

The most commonly used information sources overall were internet and videos (87%), books and library (66%), and classes and workshops (57%) (Table 2). The average number of information sources used per respondent was significantly lower ($p < 0.001$) for hobbyists (4.4 ± 1.9) than producers (5.4 ± 2.1) and educators (5.5 ± 2.2). Overall, the number of information sources was significantly and positively correlated with years of aquaponic experience ($r = 0.289$, $p < 0.001$), number of training sources used ($r = 0.347$, $p < 0.001$) (Table 1). Table 3 provides a list of benefits and drawbacks for each of the information resource categories.

The most commonly desired information resources overall were other aquaponic growers (40%), followed by Extension agents (38%), classes/workshops (37%), Extension publications (36%), and manufacturers/suppliers (34%) (Table 2). Classes and workshops, as well as manufacturers / suppliers, were desired by hobbyists. Extension agents and publications were preferred by producers. Peer-reviewed journals were desired by hobbyists and producers, but currently in use by educators. Consultants were desired more commonly by hobbyists and educators than by producers. The average number of desired information sources was 3.0 ± 1.5 per hobbyist, 2.7 ± 1.3 per producer, and 2.6 ± 1.2 per educator, which were not significantly different ($p > 0.05$) among groups.

The top three unused resources across all groups were friends and family, consultants, and social media (Table 2). The average number of unused information sources was 3.0 ± 1.3 per hobbyist, 2.7 ± 1.4 per producer, and 2.7 ± 1.2 per educator, which were not significantly different ($p > 0.05$) between groups.

Table 2. Informational resources used by aquaponic hobbyists, producers, and educators.

	Hobbyist (*n* = 85)		**Producer (*n* = 127)**		**Educator (*n* = 86)**	
Currently Used Resources	**Count**	**%**	**Count**	**%**	**Count**	**%**
Internet/Videos	76	89	112	88	71	83
Books/Library	57	67	81	64	58	67
Classes/Workshops	39	46	80	63	52	60
Peer-Reviewed Journals	25	29	63	50	58	67
Other Growers	28	33	64	50	45	52
Social Media	44	52	63	50	36	42
Extension Publications	29	34	50	39	47	55
Manufacturers/Suppliers	32	38	61	48	28	33
Extension Agents	20	24	38	30	33	38
Consultants	5	6	44	35	21	24
Friends/Family	20	24	27	21	22	26
	Hobbyist (*n* = 69)		**Producer (*n* = 108)**		**Educator (*n* = 73)**	
Desired Resources	**Count**	**%**	**Count**	**%**	**Count**	**%**
Other Growers	31	45	40	37	28	38
Extension Agents	26	28	46	43	24	33
Classes/Workshops	31	45	35	32	26	36
Extension Publications	24	35	44	41	22	30
Manufacturers/Suppliers	31	45	31	29	24	33
Consultants	22	32	25	23	22	30
Peer-Reviewed Journals	24	35	37	34	12	16
Books/Library	12	17	18	17	8	11
Social Media	4	6	10	9	6	8
Internet/Videos	1	1	8	7	6	8
Friends/Family	4	6	5	5	7	10
	Hobbyist (*n* = 72)		**Producer (*n* = 101)**		**Educator (*n* = 73)**	
Unused Resources	**Count**	**%**	**Count**	**%**	**Count**	**%**
Friends/Family	41	57	72	71	46	63
Consultants	46	64	44	44	32	44

Social Media	24	33	40	40	35	48
Extension Agents	26	36	24	24	20	27
Manufacturers/Suppliers	10	14	22	22	21	29
Peer-Reviewed Journals	22	31	17	17	8	11
Extension Publications	17	24	19	19	8	11
Books/Library	9	13	17	17	10	14
Other Growers	12	17	10	10	4	5
Classes/Workshops	8	11	5	5	6	8
Internet/Videos	1	1	4	4	2	3

Table 3. Benefits and drawbacks of various information sources for aquaponics.

Information Resource	Benefits	Drawbacks
Peer-Reviewed Journals	High quality information Peer-review accountability Internet-based Open access journals	Few publications available Not always relevant Hard to understand Cost Non-interactive
Extension Agents	Good information Interactive Provide hands-on assistance Provide training Networking potential	Few agents trained in aquaponics Low local availability
Extension Publications	Good information Easy to understand Internet-based High accessibility Free of charge	Few publications available Non-interactive Not always relevant Not well known Variation in quality
Internet Videos	Internet-based Highly accessible Easy to understand Free of charge	Potential for misinformation Variation in quality Non-interactive Not always relevant
Social Media	Internet-based Highly accessible Interactive Networking potential	Potential for misinformation
Friends and Family	Interactive	Potential for misinformation Not always relevant
Books and Library	Comprehensive High quality information	Non-interactive Not always relevant Few publications available Variation in quality
Workshops	Relevant information Provide hands-on assistance Provide training Interactive Networking potential	Cost Variation in quality Potential for misinformation

Information Resource	Benefits	Drawbacks
Consultants	Interactive Relevant information Networking potential	Cost Variation in quality Potential for misinformation
Suppliers	Interactive Relevant information Networking potential	Requires Purchase Variation in quality Potential for misinformation
Other Growers	Good information Interactive Relevant information Networking potential	Low availability Potential for misinformation May not be willing to help

DISCUSSION

INFORMATION ACCESSIBILITY

Aquaponics is multifaceted, requiring a diverse skillset to be successful, which presents unique challenges during the early stages of development (Hart et al., 2013; Goddek et al., 2015; Greenfeld et al., 2020a). Many stakeholders pursue aquaponics as an expansion of their current interests in aquaculture or horticulture (Villarroel et al., 2016), which has implications for where they seek information. Lack of access to relevant and reliable information can cause growers to waste significant time and money learning system design and production techniques through trial and error. Newcomers may feel a naive sense of self-confidence in managing their system while their actual troubleshooting skills may be inadequate (Mchunu et al., 2018). This is likely related to a lack of awareness of true challenges (Cline, 2011) and the abundance of unvetted reference materials available online (Turnsek et al., 2020). Compared to other areas of agriculture, the number and ratio of internet searchable resources that are non-peer-reviewed compared to peer-reviewed is quite high for aquaponics (Linden and Fenn, 2003; Junge et al., 2017). At the time of this publication the 'hype ratio' (e.g. google search results : google scholar search results) for "aquaponics" is 967:1 compared to "hydroponics" (859:1), "aquaculture" (13:1), "horticulture" (37:1), "sustainable agriculture" (162:1), and "agriculture" (257:1).

As the industry grows and government awareness and regulation increase for aquaponic practitioners, the need for quality information to dispel myths also increases. None of the competency areas stood out as overwhelmingly accessible, indicating that stakeholders could benefit from informational resources on each topic. Deficiencies in accessibility for MFP, FRK, FHD, PPD, FS, and SC should be addressed for information resource development and presented appropriately for each stakeholder group.

Knowledge limitations exist for secondary (i.e. consultants, manufacturers, suppliers, and service providers) and tertiary groups (i.e. regulatory agencies, media, food retailers, consumers, animal rights groups, non-government organizations, and general public) (Campbell et al., 2015; Zugravu et al., 2016; Short et al., 2017; Miličić et al., 2017; Greenfeld et al., 2020a & b). Lack of awareness can negatively affect consumer willingness to pay more for safe, sustainable, and locally produced aquaponic products (Abbey, 2018; Yue et al., 2020). Consumer education could potentially be achieved through news sources as well as at the retail store level because consumers tend to display trust and preference in these outlets (Zugravu et al., 2016; Short et al., 2017). Also, as US granting agencies become more aware of aquaponics and its positive potential, research funding is becoming more available. Access to quality information is needed for all these groups.

INFORMATION RESOURCE USAGE

All stakeholders used multiple aquaponic information sources, with the most common being internet and videos, books and library, and classes and workshops. The theme among these resources is comprehensive coverage of topics and relevance for specific needs (Table 3). Flanagin and Metzger (2000) suggest that consumers find internet resources to be equally credible as television, radio, or magazines, yet there are concerns over the potential for inaccurate or biased information. Internet video accessibility, quality, shareability on social media, and entertainment value are likely the greatest contributing factors for their use (Yang, 2007). With the prevalent use of the internet and smart devices, the trend is towards short snippets of information rather than in-depth instructional content (Cheng et al., 2013). However, when stakeholders really need to dig into the details, they tend to triangulate the validity of information with trusted sources like books, peer-reviewed literature, research-based Extension resources, workshops and experienced farmers (Cooley and Parks-Yancy, 2019). Non-academic stakeholders may not have access to peer-reviewed literature, making resource utilization an access limitation. Further, the language used in scientific publications is often difficult to understand for the general public, requiring synopsis with broad audience appeal in Extension publications or trade articles. Credible information providers should focus on delivering content with the end user in mind, with attention to relevance, stylistic quality, appearance, media type, user interface, understandability, and organization (Wathen and Burkell, 2002; Yang, 2007; Lock and Seele, 2017; Nagy, 2018).

Desired resources were other growers, Extension agents, classes/workshops, Extension publications, and manufacturers/suppliers. Common themes in these resources were networking opportunities and content delivery with general audience appeal (Table 3). While other farmers and Extension agents were highly desired resources their less frequent use was likely either an awareness (Cline, 2011) or accessibility issue. Other farmers are likely to have the highest

credibility because their experiences are directly relatable. Extension agents provide free information and feedback, but there are relatively few trained Extension professionals in aquaponics. Many of the current class/workshop training opportunities are not associated with accredited university programs, although some do exist.

The most unused resources by survey respondents included friends/family, consultants, and social media, whose lack of use is likely due to lower perceived quality and rigor of the information, and in the case of consultants, cost. The number of aquaponic information resources continue to increase, produced both by researchers and enthusiasts. Misinformation about best practices provided by so-called 'experts' on the internet promising high return on investment and minimal effort has led to failures for some start-up aquaponic businesses (Turnsek et al., 2020). As the rate of scientific research publications increases relative to other non-scientific resources, the "hype ratio" decreases (Junge et al., 2017). There is a need for free, credible information on aquaponics to be widely available and easily accessible.

RECOMMENDATIONS

Education and training opportunities to help newcomers could be very helpful during the startup phase, but due to the newness of aquaponics, these programs are relatively rare. Informal education opportunities such as workshops, seminars, field days, site visits, webinars, and internet videos are highly valued across groups. Internet resources, like YouTube videos, webinars, websites, and online publications are the most used and widely available sources of information. Yet hands-on learning and networking opportunities are typically preferred to reinforce aquaponic concepts. Because few training opportunities exist, travel expenses can limit program accessibility to would-be participants. Online alternatives, such as webinars and distance education classes, could be employed to reduce program cost and increase access and participation. Additionally, with the recent efforts to promote diversity, equity, and inclusion in educational programs, Extension agents must carefully consider their marketing strategy to ensure that their intended audience is reached.

From a design aspect, sources of credible information should focus on delivering content with emphasis on appearance, presentation, and usability (Wathen and Barkell, 2002; Yang, 2007). As online resources increase in number, dated and low production value content tend to be dismissed, regardless of the quality of the content. Media production professionals should be engaged to improve product quality. Extension personnel are encouraged to plan, budget, and collaborate appropriately when designing resources to ensure their usefulness and longevity.

To build a programmatic pipeline for stakeholder engagement, educators could initially focus their information delivery efforts on short, attention-catching videos to gain interest. Then users can be directed to more in-depth training opportunities like lectures, hands-on activities, site visits, and value stream exercises to impart knowledge, perspective, and confidence that aquaponic enterprises can be viable. A holistic suite of topics including system design, production, pest and disease management, harvesting, food safety, economics, and marketing would be a good starting point for content development. However, each program should be catered to the needs of the participants by surveying their knowledge and goals during the program planning stage. Workshops may vary in content, format, and cost by their duration, but a combination of technical knowledge and hands-on experience should be targeted.

Furthermore, building the aquaponics industry will require workforce development. Research and demonstration facilities, in conjunction with long-term high school or university education programs, could generate the necessary skilled labor pool. Additionally, there are few Extension educators trained in aquaculture and aquaponics (Swann and Morris, 2001). Train-the-trainer workshops and in-service training would be a great way to increase the number of teachers and Extension agents at US Land-grant universities with a background in aquaponics.

Regional aquaculture Extension contacts are typically aware of upcoming training opportunities featuring aquaponics, such as master gardener, 4-H, state, and regional aquaculture events. Nationally, the Aquaponics Association and the US Aquaculture Society host annual conferences featuring cutting edge research, community projects, commercial production, and education tracts to engage various stakeholder groups. Extension agents should be directly involved with each of these educational platforms.

The desire for other growers as an information resource was common in this study, and could be facilitated through educational programs like classes/workshops, webinars, online classes professional associations, and social media. Connections with social and professional aquaponic groups could provide a support network for new growers when they become discouraged during startup. Such associations could be influential in public education and affect government policy. Although social media can be a great platform for reaching broad and varied audiences, it is among the most unused resources. The low use of social media may be related to the perceived quality and rigor of these resources. The credibility of social media content can be improved if it comes from a reputable source, such as Extension, which should be pursued to ensure accurate and useful information is reaching intended audiences (Majid and Kanagasabai, 2007).

CONCLUSIONS

Education of aquaponic stakeholders is necessary for the future success of the industry (Goddek et al., 2015). Streamlining and standardization of practices to develop comprehensive guidelines for success should be pursued to enhance the learning timeline of stakeholders (Konig et al., 2018; Palm et al., 2018; Greenfeld et al., 2019). There are many options for informational resources, but matching content and format to stakeholder needs is critical. The role of Extension in facilitating information transfer and professional networking among growers is expected to increase. Train-the-trainer programs to strengthen the Extension knowledge and networks should be pursued into the future.

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