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KNOWLEDGE LEVELS AND TRAINING NEEDS OF AQUAPONIC STAKEHOLDERS

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ABSTRACT

Aquaponics has gained considerable attention in the past several years, attracting many new hobbyists, producers, and educators. Past failures of commercial farms call into question aquaponics as a viable agriculture business. This study assesses the importance (I) that growers place on nine core aquaponic competencies, as well as their knowledge (K) and access to quality information (A) on those topics. Core competencies included system design (SD), system construction (SC), system maintenance (SM), water chemistry (WC), fish health and disease (FHD), plant pest, disease, and nutrient deficiencies (PPD), financial record keeping (FRK), marketing food products (MFP), and food safety (FS). Median respondent importance ratings were high across groups, except for FRK and MFP, which hobbyists rated lowest. Similarly, knowledge of FRK and MFP were rated lower by hobbyists and educators. Quality information was generally rated as 'moderately accessible'. Composite importance scores were lowest for hobbyists and highest for producers, indicating that producers took all topics more seriously. Likewise, composite knowledge scores were lower for hobbyists than producers and educators, indicating hobbyists had lower overall knowledge levels. Composite accessibility scores were similar among groups. The top needs for knowledge and information access based on the mean weighted discrepancy score (MWDS) for all groups were in the areas of FHD and PPD, whereas FS, WC, SM, and SD needs varied by group. Educational content in these areas would be beneficial to new and veteran stakeholders.

INTRODUCTION

Aquaponics is an agricultural technology known to enhance water and nutrient use efficiency using a combination of recirculating aquaculture and hydroponic systems (Palm et al., 2018). Interest in aquaponics has soared in recent decades (Love et al., 2014), but with any new technology the excitement of new possibilities often blind users to the challenges of implementation (Lenden and Fenn, 2003). The interdisciplinary nature of aquaponics makes for a steep learning curve causing a low success rate for many during the early stages (Hart et al., 2013; Goddek et al., 2015; Greenfeld et al., 2020b). The relative newness also means that few individuals have the necessary knowledge and skills required for running a successful aquaponic production facility. System failures and economic uncertainty of early adopters has instilled a heightened sense of financial risk for prospective growers and financial institutions (Greenfeld et al., 2019; König et al., 2018; Villarroel et al., 2016). Education of stakeholders is necessary for the future success of the aquaponic industry (Goddek et al., 2015). Given the considerable constraints facing aquaponic producers, a comprehensive educational initiative is needed (Greenfeld et al., 2019; Konig et al., 2018; Palm et al., 2018). The lack of knowledge on important topics may be related to a lack of research in that area, accessibility barriers such as cost or professional networks, or an overwhelming abundance of non-credible information available online (Junge et al., 2017). The need for knowledge within the industry is great, yet to date there is no assessment that prioritizes topical areas for content development. This study uses a Borich (1980) assessment model where the discrepancy between current and desired conditions are considered to establish prioritized needs for competency area content and curriculum development.

This study surveyed aquaponic industry participants, namely hobbyists, producers, and educators. Study goals were to 1) identify the primary motivations for stakeholder involvement in aquaponics, 2) assess their perceptions of importance, personal knowledge, and accessibility of quality information in nine core aquaponic competency areas, 3) and prioritize topic areas for educational content development. This needs assessment is relevant for teachers, Extension educators, researchers, and supporting groups seeking to develop educational products in support of the aquaponic industry.

METHODS

SURVEY INSTRUMENT

An online survey (Qualtrics XM, Provo, UT, USA) was created to characterize respondent background and perceptions of aquaponic core competencies utilizing methods recommended by Dillman (2007) and Fowler (2009). The survey instrument included a blend of original and previous industry survey questions (Love et al. 2014; Villarroel et al., 2016; Pattillo, 2021) to collect quantitative and qualitative data. The survey instrument was piloted externally through the Aquaponics Association membership before Institutional Review Board approval (IRB Protocol No: 19-544 EX 1912). Extension networks, professional societies, and social media groups with thousands of members from a global audience were used to advertise and promote the survey throughout the industry, using the 'snowball' method to reach a greater audience (Browne, 2005; Baltar and Brunet, 2012; Love et al., 2014). The survey was advertised twice without participation incentives collecting data from December 10, 2019 to June 4, 2020. To facilitate comparisons among stakeholder groups, survey respondents self-selected as either 1) 'hobbyists' and home gardeners, 2) for-profit and not-for-profit 'producers', or 3) 'educators' [e.g. college, kindergarten through grade 12 (K-12), Extension, etc.]. The anonymous nature of data collection using social media platforms prevented an accurate response rate calculation as it was unknown how many actually saw the survey but did not complete it, therefore nonresponse error may bias our results. This publication represents a small subset of the questions from the full survey delivered by Pattillo (2021).

CORE COMPETENCIES

The specific topic areas being assessed for content development (e.g. competencies) were garnered from challenges experienced by the authors, Extension clientele and from the findings of Love et al. (2014). 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). These competencies represent the areas of facilities (SD, SC), operations (SM, WC, FHD, PPD), business (FRK, MFP), and regulations (FS).

Respondents rated the nine core competency areas on a 5-point Likert scale based on their perceived importance (I), personal knowledge (K), and accessibility of quality information (A) on that topic. The scales were coded as 1 = *not* Important/Knowledgeable/Accessible (I/K/A), 2 = *slightly* I/K/A, 3 = *moderately* I/K/A, 4 = *very* I/K/A, and 5 = *extremely* I/K/A. If all competency areas were rated by an individual respondent, the ratings were summed to obtain a composite score for each stakeholder group, providing an index (maximum score = 45) of each stakeholder's overall aquaponic I, K, and A levels.

DISCREPANCY ANALYSIS

Ideally, the importance (I) of each topic would be equal to each respondent's knowledge (K) or accessability of information (A) on that topic. The difference between the K or A rating and the I rating is a discrepancy, which is an opportunity for educators to offer more instruction or develop informational content. Discrepancies between individual I/K/A scores were calculated to determine differences between the desired (I) and current (K or A) status. For example, I – K was their importance rating minus either their knowledge rating, and I – A was their importance rating minus their accessibility of quality information rating.

Additionally, following the Borich (1980) needs assessment model, mean weighted discrepancy scores (MWDS) were calculated for each respondent in every competency area to prioritize each topic by importance for inclusion in research and educational programs. Discrepancies were weighted to emphasize their importance by multiplying them by the individual importance ratings (MWDS = [I × (I – K)] or [I × (I – A)]). This approach provides a needs assessment for training and educational materials development on each topic, where higher numbers are higher priorities.

STATISTICAL ANALYSIS

Data was compiled in the Qualtrics program and exported for data analysis in SPSS Statistic 26 (IBM, Armonk, NY, USA) and Excel (Microsoft 360, Redmond, WA, USA). Figures were developed using Prism 9 (GraphPad, San Diego, CA, USA) The reliability of the responses was evaluated manually to eliminate extreme outliers and illogical responses from analysis. Descriptive statistics (e.g. mean ± standard deviation (*SD*) or standard error (*SE*)), median (*M*) and inter-quartile range (*IQR*)), and proportions (e.g. percentage, %) were used to generalize stakeholder responses. Difference among group means were evaluated using a one-way Analysis of Variance (ANOVA) with Tukey's Post-Hoc test for pairwise comparisons among groups ($\alpha = 0.05$). Data was transformed with the natural logarithm function where appropriate to meet normality assumptions. Pearson's correlation coefficient (r) was used to measure the strength 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. Spearman's correlation coefficient (ρ) was used as a non-parametric alternative when ordinal data was analyzed. In congruence with Evans (1996), correlations were defined as very weak ($0.0 < r/\rho < 0.19$), weak ($0.2 < r/\rho < 0.39$), moderate ($0.4 < r/\rho < 0.59$), strong ($0.6 < r/\rho < 0.79$), or very strong ($0.8 < r/\rho < 1.0$). For Likert scale questions Cronbach's alpha was calculated to validate that response variables loaded together appropriately. Cronbach's alpha was 0.888 for knowledge, 0.849 for importance, and 0.893 for accessibility, indicating that the Likert scale data was 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 number of respondents (n) per question varied and is noted in each table and figure. The typical respondent was 55 to 64 years of age (37%), male (80%), white/Caucasian (75%), American (84%), and employed full time (61%), although many were retirees (20%). Detailed demographic information is provided by Pattillo (2021). Two thirds of respondents had less than 5 years of experience, with hobbyists (79%) most commonly having less than 5 years of experience (Table 1). Out of 298 respondents, 80% had some sort of training, with informal training (e.g. workshops) being the most common (64%), followed by work experience (41%), and formal training (24%) (Table 1). 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 positively correlated, albeit a weak correlation, with years of aquaponic experience ($\rho = 0.342$, $p < 0.001$), composite knowledge score ($\rho = 0.321$, $p < 0.001$) and very weak with development stage ($\rho = 0.172$, $p = 0.009$) (Table 2). The most common primary aquaponic interests were environmental sustainability and healthy food, while self-sufficiency, healthy food, fish, and education were secondary interests (Table 1). Of the 321 respondents, 57% had operational aquaponic systems (Table 1).

Table 1. Experience, training, interests, and development stage of aquaponic stakeholders.

		Hobbyist		Producer		Educator	
		n	%	*n*	%	*n*	%
Years of Aquaponic Experience	<1	25	24	29	19	16	14
	1-2	22	21	31	20	21	18
	3-5	35	34	38	24	30	26
	6-10	18	18	38	24	31	26
	11-20	3	3	15	10	10	8
	>20	0	0	4	3	9	8
	Total	103	100	155	100	117	100
Training Source	Informal Training	54	63	89	71	49	57
	Work Experience	16	19	74	59	31	36
	Formal Training	8	9	30	24	34	40
	No Training	30	35	19	15	12	14
	*N**	86		126		86	
Primary Interest in Aquaponics	Sustainability	55	53	106	68	62	53
	Healthy Food	65	63	92	59	44	38
	Fish	49	47	67	43	58	50
	Plants	47	45	64	41	42	36
	Self Sufficiency	62	60	66	43	23	20
	Education	16	15	31	20	78	67
	Making Money	11	11	60	39	10	9
	Other	10	10	21	14	9	8
	Work Requirement	3	3	10	6	20	17
	N	104		155		117	
Development Stage	Researching	16	17	12	9	20	22
	Planning	17	18	12	9	20	22
	Constructed	6	6	8	6	7	8
	Operational	56	59	79	58	48	54
	Total	95	100	137	100	89	100

*N is the number of respondents that responded to the question when there was more than one selection option.

Table 2. Pearson correlations between experience, training, information resource utilization, and composite scores of knowledge, importance, information accessibility, education, and development stage for survey participants.

	Hobbyist	1	2	3	4	5	6
1	Years of Experience	--					
2	Number of Training Sources	.415**	--				
3	Knowledge Score	.545**	.404**	--			
4	Importance Score	.103	.054	.321**	--		

5	Accessibility Score	.213	.052	.414**	.151	--	
6	Education Level	-.277*	.042	-.198	-.036	-.201	--
7	Development Stage	.378**	.016	.230*	-.281*	.082	-.279*
Producer		1	2	3	4	5	6
1	Years of Experience	--					
2	Number of Training Sources	.139	--				
3	Knowledge Score	.436**	.121	--			
4	Importance Score	.010	-.092	.250*	--		
5	Accessibility Score	.127	.019	.312**	.278**	--	
6	Education Level	.128	.031	.152	.067	-.040	--
7	Development Stage	.467**	.105	.306**	-.124	-.065	-.110
Educator		1	2	3	4	5	6
1	Years of Experience	--					
2	Number of Training Sources	.396**	--				
3	Knowledge Score	.449**	.189	--			
4	Importance Score	.184	.093	.259*	--		
5	Accessibility Score	.054	.125	.165	.146	--	
6	Education Level	.182	.159	.105	.112	.078	--
7	Development Stage	.282*	.311*	.022	.009	.185	.049

***$p \leq 0.05$, **$p \leq 0.002$;** Bonferroni adjustment for multiple correlations to minimize risk of Type I error. ($\alpha = 0.05/21 = 0.0024$).

CORE COMPETENCY RATINGS

Median importance ratings for all competencies were 'very important' (I = 4) to 'extremely important' (I = 5) except for FRK and MFP (Table 3). Hobbyists and educators rated FRK as 'moderately important' (I = 3), while producers found it 'very important' (I = 4). Hobbyists felt MFP was 'less important' (I = 2) than producers (I = 4) and educators (I =3).

Knowledge ratings generally ranged from 'slightly knowledgeable' (K = 2) to 'very knowledgeable' (K = 4) and varied by stakeholder group (Table 3). Producers and educators provided similar knowledge ratings across all competencies except for FRK where producers were more knowledgeable. All groups felt least knowledgeable about MFP, with hobbyists rating it the lowest (Table 3).

Information access was generally rated as 'moderately accessible' (A = 3) by survey participants (Table 3). Hobbyists rated SD and SC highest (A = 4) and MFP lowest (A = 2). Producers rated all accessibility of aquaponic information items similarly (Table 3). Educators rated accessibility highest for WC (A = 4), and all others as moderate (A = 3).

Table 3. Median (*M*) and interquartile range (IQR) of importance, knowledge, and accessibility of quality information ratings for aquaponic hobbyists, producers, and educators.

	Hobbyist		Producer		Educator	
* Importance Rating (I)	*M*	(*IQR*)	*M*	(*IQR*)	*M*	(*IQR*)
†SD	4	(4-5)	5	(4-5)	4	(4-5)
SC	4	(3-5)	4	(4-5)	4	(4-5)
SM	4	(4-5)	4	(4-5)	5	(4-5)
WC	4	(4-5)	5	(4-5)	5	(4-5)
FHD	4	(4-5)	5	(4-5)	5	(4-5)
PPD	4	(4-5)	5	(4-5)	4	(4-5)
FRK	3	(2-4)	4	(4-5)	3	(2-4)
MFP	2	(1-3)	4	(4-5)	3	(3-4)

FS	4	(3-5)	5	(4-5)	4	(4-5)
Knowledge Rating (K)	*M*	(*IQR*)	*M*	(*IQR*)	*M*	(*IQR*)
SD	3	(3-4)	4	(3-4)	4	(3-4)
SC	3	(3-4)	4	(3-4)	4	(3-4)
SM	3	(3-4)	4	(3-4)	4	(3-4)
WC	3	(2-4)	4	(3-4)	4	(3-5)
FHD	2	(2-3)	3	(2-4)	3	(2-4)
PPD	3	(2-3)	3	(3-4)	3	(2-4)
FRK	3	(2-3)	4	(3-4)	3	(2-4)
MFP	2	(1-2)	3	(3-4)	3	(2-3)
FS	3	(2-3)	3	(2-3)	3	(2-4)
Accessibility Rating (A)	*M*	(*IQR*)	*M*	(*IQR*)	*M*	(*IQR*)
SD	4	(3-4)	3	(3-4)	3	(3-4)
SC	4	(3-4)	3	(2-4)	3	(3-4)
SM	3	(3-4)	3	(3-4)	3	(3-4)
WC	3	(3-4)	3	(3-4)	4	(3-4)
FHD	3	(2-4)	3	(3-4)	3	(3-4)
PPD	3	(2-4)	3	(3-4)	3	(3-4)
FRK	3	(2-4)	3	(3-4)	3	(2-4)
MFP	2	(2-3)	3	(2-4)	3	(2-4)
FS	3	(2-4)	3	(3-4)	3	(3-4)

[*] Ratings based on a Likert scale where 1 = *not* Important/ Knowledgeable/ Accessible (I/K/A), 2 = *slightly* I/K/A, 3 = *moderately* I/K/A, 4 = *very* I/K/A, and 5 = *extremely* I/K/A.

[†] 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)

COMPOSITE SCORES

Producer composite scores for importance were significantly higher than hobbyists and educators ($p \leq 0.001$), and educator importance scores were significantly higher than hobbyists ($p = 0.037$) (Table 4). Composite scores for knowledge were significantly lower for hobbyists than producers ($p < 0.001$) or educators ($p < 0.001$) (Table 4). Composite scores for access to quality information were not significantly different ($p = 0.121$) among stakeholder groups (Table 4).

Table 4. Composite scores of aquaponic knowledge, importance, and access to quality information for hobbyist, producer, and educator stakeholders.

	Composite Score								
	Hobbyist			Producer			Educator		
	Mean	*SD*	*n*	Mean	*SD*	*n*	Mean	*SD*	*n*
Knowledge of Topics	25.3 ***b***[‡]	6.3	93	30.8 ***a***	6.5	139	29.3 ***a***	7.3	97
Importance of Topics	34.3 ***c***	5.6	91	39.2 ***a***	5.4	139	36.5 ***b***	5.8	95
Access to Quality Information	27.1	8.0	75	29.3	6.3	125	29.4	6.0	74

[‡] Comparisons should be made by row between groups. Letters denote statistically significant differences ($p < 0.05$) between stakeholder groups. Only significant differences are noted.

CORRELATION ANALYSIS

Across all groups, years of experience and composite knowledge scores were moderately positively correlated (r = 0.519; $p < 0.001$). The strength of correlations varied by stakeholder group (Table 2). Among all groups, composite scores for knowledge were weakly positively correlated with importance composite scores (r = 0.374, $p < 0.001$), and information accessibility composite scores (r = 0.334, $p < 0.001$) (Table 2). Importance and accessibility composite scores were also weakly positively correlated (r = 0.241, $p < 0.001$). Interestingly, in the hobbyist group there was a weak negative correlation between education and years of experience (Table 2).

DISCREPANCY ANALYSIS

The mean discrepancy (±*SE*) between the 'desired' and 'current' state (e.g. I – K and I – A) are presented by competency area in Figures 1-3. Hobbyist and educator discrepancies between I and K were greatest for FHD, PPD, FS, which was similar to producers, with the addition of MFP (Figure 1). Discrepancies between I and A were greatest in the areas of FHD, PPD, and FS and least in FRK and MFP for hobbyists (Figure 2). Producer I – A was similar across competencies, except for FRK, which was lower (Figure 2). Educator I – A was greatest for SM and lowest for FRK and MFP (Figure 2).

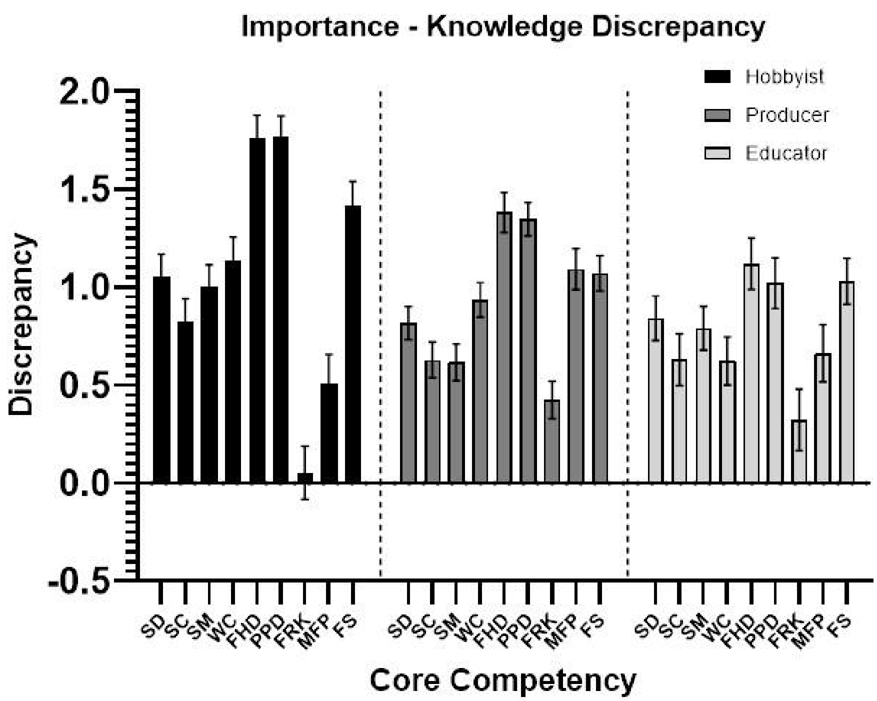

Figure 1. Mean discrepancy (±*SE*) for importance rating minus knowledge rating on a 5-point Likert scale for nine core competency areas for aquaponic hobbyists, producers, and educators. Core competencies included system design (SD), system construction (SC), system maintenance (SM), water chemistry (WC), fish health and disease (FHD), plant pest, disease, and nutrient deficiencies (PPD), financial record keeping (FRK), marketing food products (MFP), and food safety (FS).

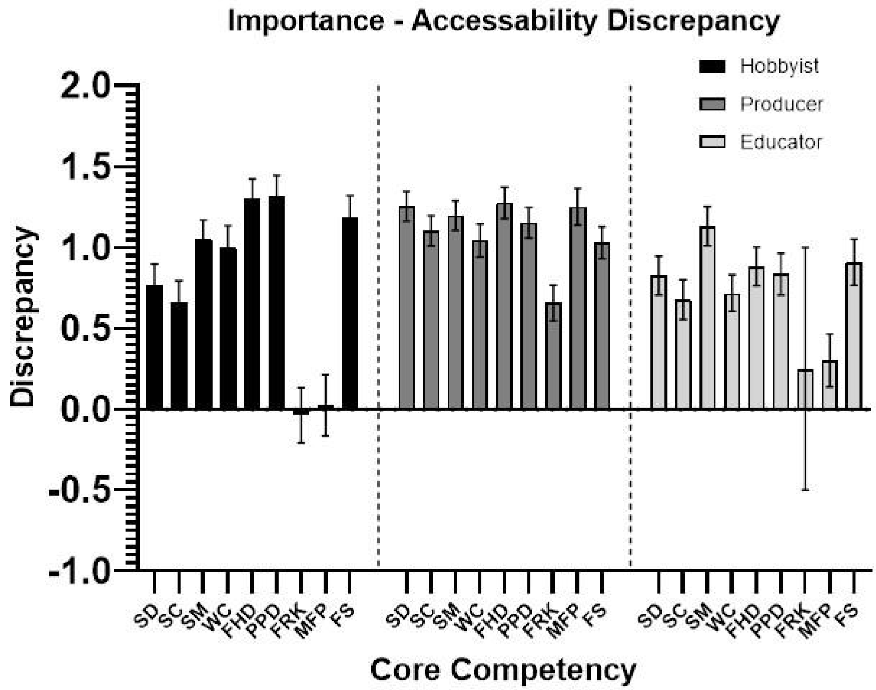

Figure 2. Mean discrepancy (±*SE*) for importance rating minus accessibility of quality information rating on a 5-point Likert scale for nine core competency areas for aquaponic hobbyists, producers, and educators. Core competencies included system design (SD), system construction (SC), system maintenance (SM), water chemistry (WC), fish health and disease (FHD), plant pest, disease, and nutrient deficiencies (PPD), financial record keeping (FRK), marketing food products (MFP), and food safety (FS).

MEAN WEIGHTED DISCREPANCY SCORE (MWDS)

Based on MWDS the top needs for knowledge and information for all groups were in the areas of FHD and PPD, while other topic needs varied by group (Table 5). In descending MWDS order, hobbyists lacked knowledge in FS, WC, SD, SM and SC relative to topic importance. Producers showed a need for knowledge in FS, WC, SD, and MFP. Educator knowledge was particularly lacking for MFP, FS, and SD. Knowledge MWDS was significantly higher for hobbyists compared to educators for FHD (p = 0.001) and PPD (p = 0.026), but significantly lower for MFP (p = 0.007) (Table 5).

Information access needs varied by group but were more common in the areas of FHD, PPD, SM, FS, and SD. Hobbyist information needs were greatest for FHD, PPD, FS, SM, WC, and SD. Producers had greatest information needs for SD and FHD, followed by MFP, SM, PPD, WC, FS and SC. Educator information needs were highest for SM, followed by FS, FHD, SD, and PPD. Hobbyists information access MWDS was significantly lower than producers for SD (p = 0.011) and MFP ($p < 0.001$) (Table 5).

Table 5. Mean weighted discrepancy score for differences between aquaponic topic importance and topic knowledge or access to information.

Mean Weighted Discrepancy Score*						
	Importance - Knowledge			Importance - Info Access		
Topic Area †	**Hobbyist**	**Producer**	**Educator**	**Hobbyist**	**Producer**	**Educator**
FHD	8.00 a‡	6.64 ab	5.41 b	6.01	6.12	4.29
PPD	8.11 a	6.38 ab	4.84 b	6.23	5.55	4.05
FS	6.43	5.21	4.83	5.43	5.10	4.64
SM	4.72	3.09	3.80	4.93	5.59	5.48
SD	5.00	4.05	4.05	3.87 y‡	6.15 z	4.10 yz
WC	5.22	4.56	3.10	4.83	5.13	3.55
MFP	2.72 b	3.39 ab	5.24 a	1.74 y	5.99 z	3.11 y
SC	3.90	3.10	3.14	3.31	5.10	3.34
FRK	1.12	2.25	2.29	1.04	3.21	2.36

* MWDS = [Importance × (Importance – Knowledge or Access)]

‡ Comparisons should be made by row between groups. Letters denote statistically significant differences ($p < 0.05$) between stakeholder groups. Only significant values are reported.

† Topic areas appear in descending order based on average MWDS for knowledge and access. 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)

DISCUSSION

PRIORITIES AND IMPORTANCE

Similar to Love et al. (2014), the primary interests in aquaponics stemmed from environmental sustainability, healthy food, fish and plant production, and self-sufficiency. Making money and education were also important for producers and educators, respectively. Personal priorities tend to vary across stakeholder group and location and are often skewed by personal and professional backgrounds (Hart et al., 2013; Love et al., 2014; 2015a, 2015b; Genello et al., 2015; Villarroel et al., 2016). In this study, the importance ratings for each competency indicate the priority level that respondents placed on them (Table 3).

The I/K/A levels of aquaponic stakeholders were not uniform across groups. The positive correlation between importance, knowledge, and accessibility indicates that respondents were more willing to find and learn information if they found it important (Table 2). Hobbyists I/K/A ratings were generally the lowest for each competency (Table 3). Because hobbyists are typically involved in aquaponics for fun, it is not necessary for them to become an expert in all areas of aquaponics, especially the business (e.g. FRK and MFP) and regulatory (e.g. FS) aspects. Producers generally provided the highest I/K/A ratings for each competency area. This is likely because they have invested much of their own time and capital into the success of their operation and are likely to be more diligent about seeking and gaining knowledge in each of the competency areas. Educators generally fell between hobbyists and producers in terms of their I/K/A competency ratings. This is likely because they take the success of their system more seriously than hobbyists and understand the need for knowledge in all the core competency areas so they can successfully teach the core topic in their classes and demonstration units. However, the need to be proficient in the business and regulatory competency areas is not critical for most educators as it does not directly affect their livelihood, therefore other work responsibilities may take precedence.

Ratings for the accessibility of quality information assesses the ease of obtaining relevant and beneficial information. The size of discrepancies between importance ratings and knowledge or information access ratings indicated a relative need in that core competency area.

KNOWLEDGE AND EXPERIENCE

Knowledge is a common barrier to successful aquaponic adoption by stakeholders (Hart et al., 2013; Greenfeld et al., 2019; 2020b). The core competencies chosen for analysis in this study related to inherent risks to newcomers (Hollyer et al., 2009; Tyson et al., 2011; Engle and Stone, 2013; Engle, 2015; König et al., 2018). The effort required for mastery of all aspects of aquaponics can be tremendous and the timeframe for obtaining the skills needed to succeed is relatively short (Greenfeld et al., 2020b). Finding skilled labor is a challenge for aquaponic producers because there are very few quality training opportunities, thus, employees are trained frequently on the job (Goddek et al., 2019; Milliken and Stander, 2019). Knowledge limitations also exist for secondary (i.e. consultants, manufacturers, suppliers, service providers) and tertiary groups (i.e. regulatory agencies, media, food retailers, consumers, animal rights groups, NGOs, general public) (Campbell et al., 2015; Zugravu et al., 2016; Short et al., 2017; Miličić et al., 2017; Greenfeld et al., 2020a & b).

In this study, there was a moderately positive correlation between user knowledge and years of experience, suggesting that hands-on experience is necessary to develop the knowledge and skills required to be successful in aquaponics. The weak negative correlation between education level and years of experience may be due to a generational difference, with older respondents not pursuing higher education. Untrained or inexperienced growers may use troubleshooting tactics that can actually harm their system rather than getting the desired benefit, like overfeeding the fish to boost nutrients for plants (Mchunu et al., 2018). Growers might feel more confident in their knowledge levels early in the learning process but are unaware of challenges simply because they have not yet experienced them (Cline, 2011). For example, certain fish species can be particularly difficult to raise, especially when one does not have a firm grasp of water chemistry and fish health. Making improper water quality modifications can actually lead to stress and disease in fish (Pattillo, 2014).

The relatively low percentage of respondents with operational facilities (57%) in this study indicates a large group of practitioners in the startup phase need practical information. Two thirds (66%) of all respondents had less than five years of experience compared to 89% reported by Love et al. (2014), indicating a potential increase in grower retention of 23% beyond the five-year mark. In this study, hobbyists had the least experience, with 79% having five years or less compared to 63% of producers, and 58% of educators (Table 1). When considering the positive relationship between experience and knowledge, it is important to increase grower retention to improve overall industry knowledge and success. Extension and education programs and industry associations represent opportunities for recruitment and retention of growers.

TRAINING ACCESS NEEDS

In this study, overall priority areas for content development dealt with fish and plant production and management. Cline (2011) found the greatest discrepancy for aquaculture educators in the area of controlling diseases and pests in aquatic environments and fish health management, which is consistent with the high MWDS for FHD in this study. Kennel (2009) found the greatest MWDS in pre-service agricultural teachers in the areas of plant identification, effects of pesticide use, identification of common pests and diseases, and maintenance of greenhouse irrigations systems both before and after instruction, indicating that these concepts may be difficult to grasp (Kennel, 2009).

FACILITIES

Facility-related competencies were SD and SC. Understanding local climate effects and how they play into system design, fish/plant choices, production costs, expected sales price, and profitability are critical to success (Rakocy et al., 2004; Engle 2015; Love et al., 2015c; Goddek and Körner, 2019). Environmental control for plant production requires providing appropriate light, temperature, humidity, airflow, integrated pest management and other factors that influence plant production. Respondents understood that SD was extremely important (I = 5), and they felt they were very knowledgeable (K = 4) but felt that access to quality information on this topic was only moderate (A = 3).

OPERATIONS

Operational competencies used daily by all stakeholder groups included SM, WC, FHD, and PPD, which were generally rated of high importance (I = 4 to 5), but knowledge levels varied (K = 2 to 4) (Table 3). Tyson et al. (2011) suggested that operations and management factors such as optimizing the production environment (e.g. water chemistry, pH, biological filtration, temperature, and light), maximizing production outputs (e.g. fish and plants), and minimizing effluent discharge into the environment are the top sustainability challenges. Careful management of energy, labor, water and other plant and fish inputs are necessary for production ease and efficiency and minimizing production costs (Hart et al., 2013; Love et al., 2015a & c). Selecting compatible, easy-to-grow, locally available fish and plant species that are disease resistant and have good market value is a challenge for growers (Bailey and Ferrarezi, 2017). Additionally, managing both subsystems to optimize health and production output can be difficult, but more management options are available for decoupled systems (Monsees et al., 2017; Yep and Zheng, 2019).

BUSINESS

The greatest variability in importance ratings existed for the business topics (FRK and MFP) with producers rating them highest and hobbyists rating them lowest (Table 3). Business skills are critical for producers but not as important for hobbyists or educators who are not bound by the need to make a profit. Recording the cost of production and sales receipts are important for any business and great care should be given to these details. Marketing requires connecting to clientele that are willing to pay a premium for aquaponic products (Short et al., 2017). Aquaponic product demand is often low and production cost is often high, discouraging investment at appropriate system scale to operate profitably (Xie and Rosentrater, 2015; Quagrainie et al., 2017), therefore production cost and markets for fish and plants should be researched before beginning system construction. Unfortunately, consumers are generally unaware of aquaponics (Zugravu et al., 2016; Short et al., 2017; Miličić et al., 2017; Greenfeld et al., 2020a) and this lack of recognition generally negatively affects product price (Abbey, 2018; Yue et al., 2020). Consumer education through news sources or retail stores could be beneficial because consumers tend to display trust in these outlets (Zugravu et al., 2016; Short et al., 2017). Education on multiple levels will be necessary to move the industry forward.

REGULATIONS

There are many regulatory areas that aquaponic farmers must keep up with to operate in the current sociopolitical environment (Engle and Stone, 2013; Goddek et al., 2015). In the US, regulatory issues associated with aquaponics are broad, with the involvement of multiple regulating agencies (Engle and Stone, 2013; Tomlinson, 2015). Food safety standards are stringent, requiring processing facilities that meet the Hazard Analysis and Critical Control Point (HACCP) certification and Food Safety and Modernization Act (FSMA) criteria for sanitation (Elumalai et al., 2017). Food safety (FS) was rated of high importance (I = 4 to 5) by all groups, but their knowledge was low (K = 2 to 3) and information access was moderate (A = 3 to 4). This is a critical area of need as it directly impacts commercial producers.

RECOMMENDATIONS

Recommendations for newcomers to aquaponics from the author’s perspective would be to find high-quality local, regional, and/or national training opportunities to attend, learn from and network with like-minded individuals (e.g. Aquaponics Association, World Aquaculture Society, US Aquaculture Society, American Society for Horticultural Science, etc.), especially during the startup phase. It is necessary to properly train Extension agents in aquaponics to provide these services and expand the knowledge network. This can be done through train-the-trainer workshops and university-level curriculum in aquaponics. A local or university-based aquaponic demonstration facility could provide year-round access and courses to provide technical advice and internship opportunities to foster skill development. This would also benefit agriculture educators, who can train students in aquaponics and expand interest and workforce training opportunities at multiple levels. A one-day workshop could introduce aquaponic system choices, specifics of how to grow fish and plants, water quality, marketing, etc., but would be short on any hands-on experiences. A three-day workshop could cover the basics in more depth, mix in with hands-on experiences, and a visit to an operating aquaponics site. A seven-day workshop could provide more detail on technical aspects, add more hands-on activities, and add a section on pricing and marketing of products. Ideally, the topic areas of system cost, capital and equipment needs, water source, plant and fish production specifics, pest/disease control, watering, harvesting, processing, and marketing should be included to some degree in any length workshop. Reduced program cost and increased accessibility could be accomplished through online instructional opportunities such as webinars and periodic online distance education workshops.

CONCLUSIONS

More Extension agents and educators should be trained in aquaponics to provide opportunities and informational resources in a variety of individual and group formats for participants to learn and network. Core competency areas evaluated in this study should be covered during trainings to varying degrees based on the target audience, their needs, and their knowledge level. Delivery methods such as lectures would impart knowledge, hands-on activities would provide confidence, site visits would demonstrate, and value stream exercises would give assurances that aquaponic enterprises can be viable. Each State’s Land Grant University system should be available to help newcomers and train students in aquaponics to fill the roles of skilled workers, entrepreneurs, consultants, manufacturers, suppliers, teachers, researchers, and Extension agents.

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