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Development of Bighead Catfish (*Clarias macrocephalus*) Culture for Sustainable Aquaculture in Cambodia

Workshop report

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Development of Bighead Catfish (*Clarias macrocephalus*) Culture for Sustainable Aquaculture in Cambodia Workshop report

Authors

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In partnership with

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List of abbreviations

BC	bighead catfish
BCC	bighead catfish culture
CAST	Commercialization of Aquaculture for Sustainable Trade
CE SAIN	Center of Excellence on Sustainable Agricultural Intensification and Nutrition
FARDeC	Freshwater Aquaculture Research and Development Center
FCR	feed conversion ratio
FiA	Fisheries Administration
FiAC	Fisheries Administration Cantonment
FM	fishmeal
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
NGO	nongovernmental organization
RAS	recirculating aquaculture system
RUA	Royal University of Agriculture
SBM	soybean meal

Introduction

Objectives

The purpose of the Workshop on Development of Bighead Catfish (*Clarias macrocephalus*) Culture for Sustainable Aquaculture in Cambodia was to share ongoing research on bighead catfish (BC) in Cambodia and discuss the next possible steps with all the participants, building on current activities and opportunities available in the country.

Date and venue

The one-day workshop took place on Wednesday, June 28, 2023, at the Royal University of Agriculture (RUA) in Phnom Penh, Cambodia (Appendix A).

Participants

Forty-six people attended the workshop, representing the following organizations (Appendix B):

1. RUA
   - Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN)
   - Faculty of Fisheries and Aquaculture
2. Fisheries Administration (FiA)
   - Fisheries Administration Cantonment (FiAC), Takeo province
   - Fisheries Administration Cantonment (FiAC), Prey Veng province
   - Freshwater Aquaculture Research and Development Center (FARDeC)
3. International nongovernmental organizations (NGOs)
   - Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
   - Commercialization of Aquaculture for Sustainable Trade (CAST)
4. Local NGOs
   - Akphivath Neary Khmer Organization
   - Hurredo Organization
   - Trailblazer Cambodia Organization
5. Consultants
   - GFA Consulting Group
6. Local feed companies
   - Agri-Master Company
   - Apsara-Agri
7. Bighead catfish farmers
8. Cambodia Aquaculturist Association
9. WorldFish Cambodia
10. WorldFish Headquarters
11. Interpreter

1. Agenda

1.1. Opening

The workshop began with the emcee welcoming all participants and inviting everyone to stand up to honor the Cambodia National Anthem. Next, Dr. Hok Lyda, representing the RUA, thanked all project partners for their collaboration and guidance in developing BC aquaculture.

Afterward, Dr. Sithirith Mak, the WorldFish country manager in Cambodia, was honored for the three years of collaboration between WorldFish and the RUA on the BC project. He welcomed everyone and complimented the farmers who shared their knowledge with the students.

Next, Ms. Kaing Khim, representing the FiA, delivered a warm welcome speech addressing the significance of fish as a staple food in Cambodia and highlighting the challenges of limited supplies. In her address, she emphasized the goal of achieving a 20 percent annual increase in agriculture, which has not yet been accomplished, stressing the importance of at least a 10 percent increase. Furthermore, Ms. Khim proposed a strategic focus on cultivating a single species, BC, which holds a special place in the hearts of the Cambodian people as their favorite fish.

1.2. Presentations and on-site visit

The workshop featured six presentations and included an on-site visit by representatives of the partner institutions (Appendix C–H). They are listed in their chronological order of the workshop:

- Presentation 1: Overview of workshop objectives and expected outcomes
- Presentation 2: Bighead catfish project in Cambodia
- Presentation 3: Wet laboratory built for the bighead catfish project
- Presentation 4: First experiment on bighead catfish in the wet laboratory
- On-site visit of the wet laboratory and pond of the RUA
- Presentation 5: Second experiment ongoing on bighead catfish in the pond
- Presentation 6: Upcoming fish nutrition experiments

Plate 1. The opening ceremony of the workshop starting with the singing of the Cambodian National Anthem.

Presentation 1: Overview of workshop objectives and expected outcomes

Dr. Rodrigue Yossa

1. Introduction to the role of each project partner
    - WorldFish and Texas A&M University are involved in technical assistance and capacity building.
    - Kansas State University is involved in coordination.
    - The RUA and CE SAIN are involved in implementation, training and reporting.
2. Overview of the project from 2020 to 2023
    - The purpose of the project is to research and develop bighead catfish culture (BCC).
    - The objectives of the project are to (i) build the human and institutional aquaculture research capacity of the Faculty of Fisheries and Aquaculture at the RUA and (ii) develop and scale cost-effective feeds for the sustainable culture of BC in Cambodia.
    - Kansas State University developed technology protocols and human infrastructural capacity.
    - Outputs of the project include sustainable feeds, one research facility, two research papers, one technical guide/feeding protocol and eight internship reports.
    - BCC has been disseminated for sustainable aquaculture in Cambodia.
3. Explanation of the workshop objectives
    - Tell local stakeholders about the ongoing project.
    - Share the achievements of the project.
    - Present upcoming activities.
    - Solicit feedback from stakeholders.
4. Explanation of the workshop outputs with specified rankings
    - BC health management occupies 20 percent of the project.
    - BC breeding takes up 50 percent.
    - BC husbandry accounts for 30 percent.
5. A workshop report with a concept note will provide guidance for the next steps of sustainable farming of BC in Cambodia.

Presentation 2: Bighead catfish project in Cambodia

Mr. Sonoan Kry

1. The goal of the project
    - Develop and apply new technologies on formulated sustainable feeds for BCC that will increase income, promote gender equality, empower youths, provide nutritious food and strengthen resilience in Cambodia, while building the capacity of local institutions to expand the farming of this species.
    - Gender: Women and men will participate in identifying unique gender roles in BC feeding and the management of an aquaculture facility. The design of the training program will meet the needs of women, offering daycare services and flexible work schedules to accommodate the participation of both women and men.
    - Youth: Raksmey Sophorn High School, the RUA, Royal University of Phnom Penh, and National University of Battambang will all collaborate to provide education to underprivileged youths. These institutions serve as centers to engage and train youths. The team will link these universities with the CAST training project, which has ponds in three of these institutions.
    - Resilience: Instead of using underrated fish, using soybean meal (SBM) as the main source of protein in BC diets will reduce dependence on wild catches. The team can develop resilient and predictable production and marketing management protocols for "vegetarian" BC, reducing the extraction of wild fishstocks from the Mekong River Basin.
    - Capacity building: WorldFish Headquarters, Texas A&M University and Kansas State University will collaborate to strengthen the fish research, education and extension capacities of the RUA.
2. Description results measurement approach
    - Produce a blueprint to start a wet aquaculture laboratory for fish nutrition research in Cambodia.
    - One wet aquaculture laboratory will operate as a nutrient research facility and will publish standard operating procedures in Cambodia.

- Create protocols and reports for three fish nutrition experiments.
- Train two RUA staff, including at least one woman and one youth in Malaysia, and produce two internship reports.
- Train two RUA staff, including at least one woman and one youth, on how to formulate and manufacture feeds in the US, and produce two reports of the visit.

3. Expected deliverables
   - Train four researchers from the Faculty of Fisheries and Aquaculture on fish feeds and nutrition research and feed formulation for sustainable BCC.
   - Complete three experimental feedings in Cambodia.
   - Publish two articles.
4. Strengthening the institutional and human aquaculture research capacity of local institutions in Cambodia
   - Purchase and install materials for research into aquaculture nutrition feed so that RUA can start a wet lab.
     - Design and itemize materials required to start a wet lab.
     - Install the materials to start a wet lab for aquaculture research.
   - Train RUA personnel on scientific aquaculture research.
     - Involve the personnel in the experiments at the wet laboratory.
     - Train them on how to run a wet laboratory in Malaysia.
     - Train them on feed manufacturing through a study visit to Texas A&M University.
5. Develop and scale cost-effective feeds for the sustainable culture of BC in Cambodia
   - Trial 1: Determine protein and lipid requirement levels in the grow-out stage under lab conditions.
   - Trial 2 and Trial 3: Investigate the substitution of fishmeal (FM) and underrated fish protein with SBM in the diet of BC.
   - Develop feeding strategies for BC.
6. Challenges and solutions
   - Covid-19 caused a delay in shipping materials from Malaysia and led to delay in the installation of the wet lab.
     Solution: (A) Closely communicate with the supplier; (B) seek support from WorldFish Headquarters/Cambodia and (C) purchase alternative supplies locally.
   - There are limited supplies and technical expertise regarding the feed producing machine.
     Solution: (A) Communicate with many suppliers in Cambodia to order from China; (B) contact a consultant from Bangladesh to train the PhD student, RUA personnel and students on how to operate fish feed machines.
   - There are limited standards on ingredients to produce fish feed.
     Solution: (A) Seek advice from a technical advisory board to revise the feed formula to fit with local availabilities; (B) contact local suppliers including feed millers to supply the required ingredients.
7. Recommendations
   - The Faculty of Fisheries and Aquaculture, WorldFish and CE SAIN should continue supporting the PhD student in completing his research. This research will serve as a valuable reference for researchers and students who wish to further investigate feed formulation for BC.
   - Researchers and relevant stakeholders should continue to improve the quality and quantity of fingerlings and feed to increase the production of BC in Cambodia.
   - Take fish disease and biosecurity into consideration, as the aquaculture subsector in Cambodia is growing.

Presentation 3: Wet laboratory for the bighead catfish project

Mr. Khairul Rizal Abu Bakar

1. Introduction to the recirculating aquaculture system (RAS)
2. RAS components
   - Culture tanks: There are 40 glass aquariums (0.9 × 0.5 × 0.4 m) with an approximate capacity of 150 L.
   - Primary mechanical filter: There are 40 feces/waste collectors made from fiberglass, with 70–90 percent collecting efficiency.
   - Secondary mechanical filter: A Waterco S800 Sand Filter collects waste that passes through the primary filter.
   - Biological filter: A K1 moving bed bioreactor, bio-ball and Matala mat convert dissolved ammonia derived from fish metabolic by-products into nitrite and nitrate.
   - Water treatment area: A UV sterilizer reduces the risk of pathogens.
   - Other instruments: There are also two water pumps, two fiberglass tanks (8 x 4 x 4 m), two air blowers, and one water pump.
3. Share the designed blueprint for developing the wet laboratory

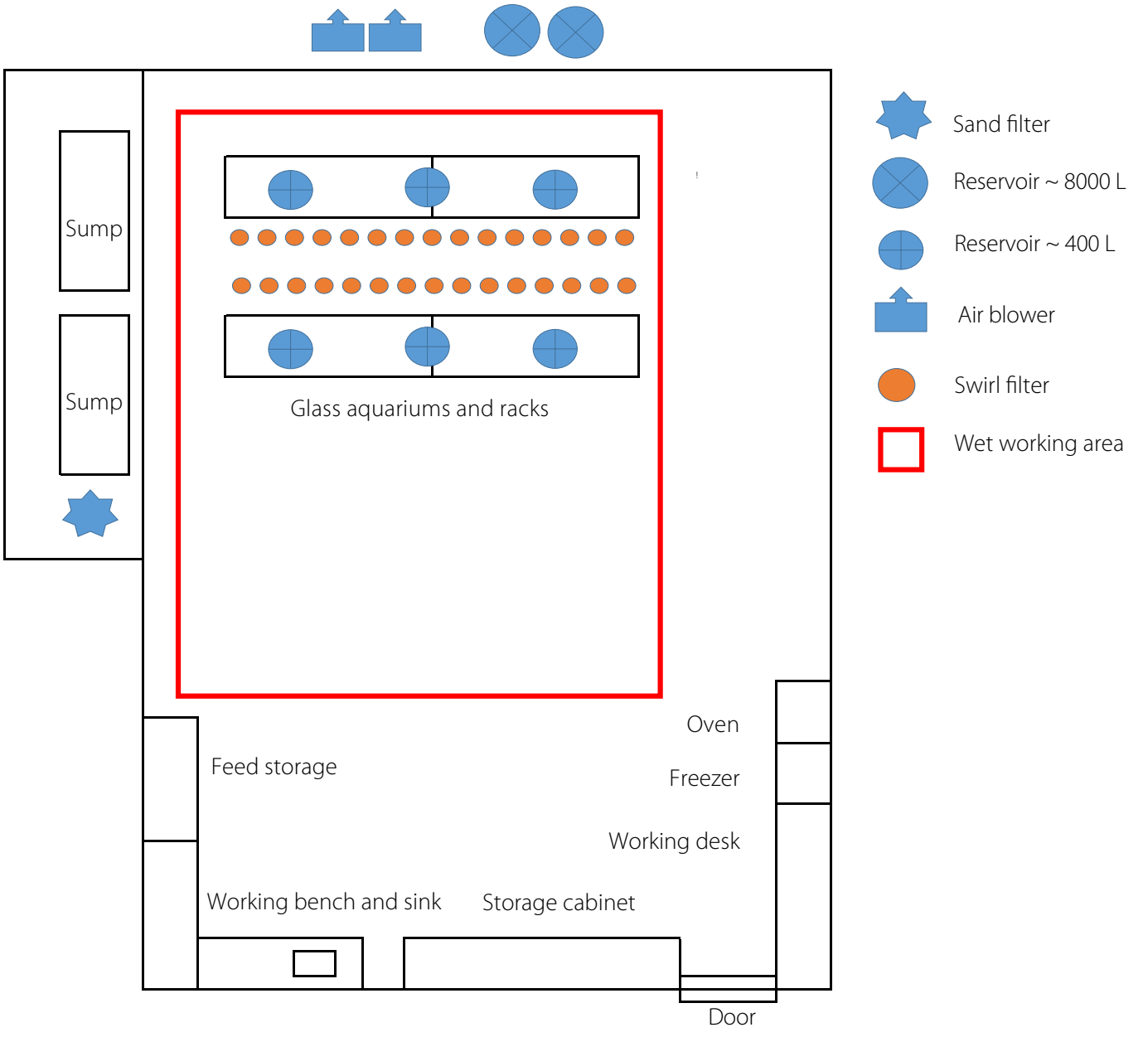

Figure 1. Blueprint of the wet laboratory.

Presentation 4: First experiment on bighead catfish in the wet laboratory

Mr. Soth Vithun (PhD student)

1. The first experiment was successfully conducted on BC in the RUA wet lab.
2. The objective of the experiment was to evaluate some of the commercially available feed for BCC.
3. The experiment used two types of commercial feeds: Ocialis from Apsara Agri Supplies (30 percent protein) and Dollar from Ly Hong Chhoy Trading Co.,Ltd (35 percent protein).
4. The fish were fed twice daily in the wet laboratory until they were full.
5. The brands did not bring significant results in growth, feed conversion ratio (FCR) or somatic index. However, feed containing 35 percent protein can promote better BCC because it improves both growth and FCR.

Questions and answers

Q: A local farmer expressed concern about the feed selection and asked for a weight comparison from the early stage of the experiment to the end stage.

A: Mr. Soth explained that only two brands of commercial feeds were chosen because the protein content had to be between 30 and 35 percent. The initial average weight of the fish was about 80 to 85 g. By the end of the experiment, the fish weighed about 120 g.

Q: A feed supplier asked for a price comparison of the feed, as there were no significant differences in the growth of fish.

A: Mr. Soth presented the price comparison with the resulting FCR during the experiment as an indicator of good feed performance, as shown in Table 1.

Q: A participant asked about a comparison of the feeding system, disease analysis (specifically the cause of disease) duration and weather. They also asked what were the sources of raw materials and types of ingredients while producing their own feed.

A: Mr. Soth said that he is not an expert in diseases.

Additional comments

A local supplier explained that diseases are different according to weather conditions. Bacteria are what often cause diseases in the hot season, and parasites are the main cause during the rainy season, while during the cold season it is fungi and viruses. A local farmer suggested that verifying the protein percentage of feed is important for fish, whether it is a crude or digested protein, because the latter supports growth.

Feed Company	FCR	Price/kg (USD)	Price/kg of fish (USD)
Dollar 30% CP* Ly Hong Chhoy	3.52	0.95	3.33
Dollar 35% CP Ly Hong Chhoy	1.72	1.02	1.75
Ocialis 30% CP Apsara Agri Supplies	2.51	0.87	2.18
Ocialis 35% CP Apsara Agri Supplies	1.74	0.93	1.63

** Crude protein*

Table 1. Price comparison for each feed with the resulting FCR.

On-site visit to the wet laboratory and pond of the RUA

Mr. Sonoan Kry and Mr. Soth Vithun

For the on-site visit, Mr. Sonoan Kry and Mr. Soth Vithun led the participants into the wet laboratory and hapas (enclosures made of fine mesh netting material placed in a pond for holding fish). The goal of the visit was to let the participants see the results of the wet laboratory built for the project and to get an overall idea of how BC was cultured in the lab and pond during the experiment.

Plate 2. Participants visiting the wet laboratory at the RUA.

Plate 3. Participants visiting the pond at the RUA.

Presentation 5: Second experiment ongoing on bighead catfish in the pond

Mr. Soth Vithun

1. The objective was to evaluate some of the commercially available feed for BCC in the pond.
2. Two types of commercial feeds were used: Ocialis from Apsara Agri (30 percent protein) and Dollar from Ly Hong Choy (35 percent protein).
3. The fish were fed three times daily in the pond until they were full.
4. Pond fish culture can have different RASs because of the dynamic productivity and water quality of the pond. Mr. Vithun will compare both systems once he finishes this experiment. Promoting aquaculture in ponds can yield favorable results for farmers and provide recommendations for aquaculture production systems.

Presentation 6: Upcoming fish nutrition experiments

Dr. Aaqillah Amr Mohd Amran

1. Introduction
   - BC is widely distributed throughout Southeast Asia and has become a popular species in aquaculture.
   - However, knowledge about the protein and lipid requirements for optimal growth of this species is still limited.
   - Using dietary protein successfully not only depends on the quantity and quality of the protein but also on a sufficient supply of lipids.
   - Adequate lipid supplementation in the feed can prohibit using protein for energy production.
2. Two protocols
   - Protocol 1: Estimate the protein and lipid requirements of BC at the juvenile stage.
   - Protocol 2: Investigate the substitution of FM with SBM in the diet of BC.

1.3. Breakout session

After the presentations and on-site visit, Dr. Rodrigue Yossa hosted a breakout session. The participants were randomly divided into five groups to brainstorm and discuss research topics of interest for the future development of BC farming in Cambodia. Each group had to suggest at least five topics of interest worth investigating (Appendix I). The results of this breakout session will guide the development of a concept note to use for future works related to BCC, which will benefit farmers and organizations.

Group 1

R&D topics of interest	Justifications	Ranking
Alternative feed to increase the survival rate of juvenile catfish	• There is a lack of alternative feeds, as only commercial feeds are available for fry. • The survival rate of fry is only 3–5 percent when farmers use commercial feeds. • A local alternative is needed to raise the survival rate up to 40 percent, as is reported for live *Moina*.	100%
Total		**100%**

Group 2

R&D topics of interest	Justifications	Ranking
Hatchery and breeding of BC	• Purify broodstock. • Increase the production of fry and fingerlings, both in quantity and quality. • Good fish nursery management practice to provide optimal conditions that support the survival and healthy growth of the fish.	50%
Feed production with local ingredients/inputs	• Production costs for feed and fish are low. • Fish farming has increased at the community level. • Vulnerable people can access safe food.	30%
Disease and management	• Diagnose and manage diseases • Disseminate fish.	20%
Total		**100%**

Group 3

R&D topics of interest	Justifications	Ranking
Economic analysis of BC feed	• Prepare the protein level, price and fish growth in the pond system. • Raise awareness and provide the best options for farmers.	25%
Study on the system of raising fish in the pond	• Understand growth rate and feeding. • Manage water parameters.	15%
Study on using fish feed ingredients	• Understand feed protocol, protein level and dryness. • Study the differences in growth rate by using each feed protocol.	15%
Study on biomass	• Study fish waste in the production cycle. • Understand water quality and also solutions for water quality problems.	20%
Study on main fish diseases	• Understand problems related to diseases, their causes and potential solutions.	25%
Total		**100%**

Group 4

R&D topics of interest	Justifications	Ranking
Nutrition requirements	• Determine the proper level of protein. • Improve fish digestion by feeding fish a digestible ingredient.	10%
Seed production	• Ensure that seed are resistant to climate change, especially during dry seasons. • Ensure that they are resistant to diseases.	30%
Broodstock purification and management	• Create year-round reproduction. • Make sure fecundity is high.	30%
Low-cost feed production	• Find local and cheap ingredients. • Proper feed management requires using feeding techniques.	20%
BCC-related diseases	• Experiment with different culture systems • Use proven treatments and medications.	10%
Total		**100%**

Group 5

R&D topics of interest	Justifications	Ranking
Diet development for BC farm	• Production costs are high. • Investigate low-cost ingredients.	30%
Quality BC seed production	• Make sure seeds are disease-free. • Ensure that growth is high.	30%
Health management	• Institute proper biosecurity measures. • Follow proper fish husbandry standards.	20%
Extension	• Strengthen the capacity of local farmers. • Create a demonstration farm.	20%
Total		**100%**

1.4. Plenary session

After the breakout session, all the groups gathered in the meeting room for a discussion, facilitated by Dr. Yossa. Representatives for each group took turns presenting the outcomes of their respective breakout sessions. Five key issues were addressed and actively discussed by all participants, who shared their perspectives and expressed their interests in these topics.

1. Broodstock

- Four groups were invited to share where they sourced the broodstock in their farms in Cambodia.

  Farmer 1: "Most of the broodstock from my farm comes from the other farms but is originally from the wild."

  Farmer 2: "I obtained the broodstock from fishermen who used a net to catch them from the local rivers. I breed them myself, though I have difficulties breeding them, but I am learning every day."

- Two groups expressed interest in purifying broodstock, emphasizing the need to assess their quality. Until now, no one has examined the quality of the broodstocks in Cambodia, which is crucial for the success of a BCC farm. During the discussion, they highlighted the challenge of tracing the origin and quality of the fish prior to cultivation on the farm.

2. Hatchery

- Breeding success in BC farming is low, with only a 3–5 percent survival rate. The participants emphasized the need to learn more about breeding techniques. Research is needed to increase the survival rate for hatcheries to earn a profit.
- Participants shared that people prefer to grow and eat fresh pure BC than hybrid African catfish male × BC female. However, when it comes to selling, people prefer African catfish or hybrid catfish because of the improved taste and texture when grilled.

3. Husbandry

- Group 5 was interested in fish husbandry.
- Apparently, there is no activity documented on the production of BC in either mono or polyculture systems.

4. Ingredients, feeds and feed management

- The presentation shared all the challenges that the BC project covered, as well as additional ideas.

5. Diseases

- Participants shared their experience during disease outbreaks in BC farms.
- Diseases in ponds usually happen after September, during the dry season, when fish develop a swollen belly.
- Red eyes and inflamed intestines are the main causes of diseases.
- Participants would also like to know more about biosecurity at the hatchery and farm level, mainly during the dry season when there is potential for disease outbreaks.

1.5. Recap and general discussion

Based on the discussion from the plenary session, we conducted a simple statistical analysis and grouped the topics into four major categories, as illustrated in Figure 2: (1) feed, (2) hatchery, (3) fish husbandry and (4) capacity building. According to the analysis, feed emerged as the most interesting topic among the participants. This aligns with industry observations that feed management incurs the highest operational costs compared to other factors. Within the feed topic, the use of alternative feed sourced from local ingredients garnered particular interest. This is because it directly relates to the use of local resources, which in turn influences the cost of feed production. On the other hand, participants showed the least interest in the nutrient requirements of feed. This suggests a lack of awareness regarding the importance of balancing nutrients in the feed for BCC. The upcoming research by a PhD student at the RUA, aiming to estimate the protein and lipid requirements of BC, aligns with this topic.

Fish husbandry ranked second, with fish quality showing the highest percentage of interest. Some participants mentioned that the fish in their ponds or tanks are mostly sourced from the wild, indicating an unsustainable practice. They expressed concerns about differentiating high-quality fish from those caught in the wild, as they often face difficulties growing fish in their ponds because of uncertainties in the quality of wild-caught fish. Additionally, one participant shared

their unsuccessful attempts at breeding fish, highlighting the need for a future project focused on improving fish broodstock quality. Figure 2 shows that practicing good fish husbandry, along with proper water quality management, can help farmers increase BC production by minimizing the risk of disease infection.

Capacity building, in this context, refers to the process of developing the skills, knowledge, resources and capabilities of individuals, organizations or communities to achieve specific goals. It specifically relates to the production of safe food within the community. The reason provided is that participants did not realize the indirect impact that capacity building could have on their farms. Despite the overall lack of interest in capacity building, two groups demonstrated interest in obtaining fish from a dissemination project focused on genetically improved seeds. The findings suggest that we should increase the number of projects that can contribute to local farmers, whether directly or indirectly. This is important to ensure the effectiveness of aquaculture in Cambodia to reduce dependence on wild catches.

Overall, the study on hatchery management garnered the least interest among participants. This suggests a lack of enthusiasm or engagement in this aspect of the study. This study showed less interest as compared to both feed and fish husbandry studies. It can be concluded that, apart from feed management, a well-executed hatchery system is crucial to ensure high BC production as it directly impacts fry availability.

1.6. Closing remarks

The workshop ended with closing remarks from Dr. Lyda Hok, the center director of CE SAIN, who expressed gratitude for the fruitful outcomes of the workshop. He thanked the participants for their attendance, acknowledging their contribution to making the event a memorable and engaging experience. Dr. Hok emphasized the value of the workshop in providing valuable insights and fostering connections among the participants. He expressed his hope for the continuity of similar workshops in the future, with the aim of enhancing the capacity of farmers and local students and at the same time contributing to the development of BCC.

1.7. Conclusion

The workshop aligned with the completion of the project. However, the PhD student will continue conducting experiments on Protocol 1 and Protocol 2, with support from CE SAIN. Future collaborations with the RUA and other partners are expected following the positive feedback received from the participants.

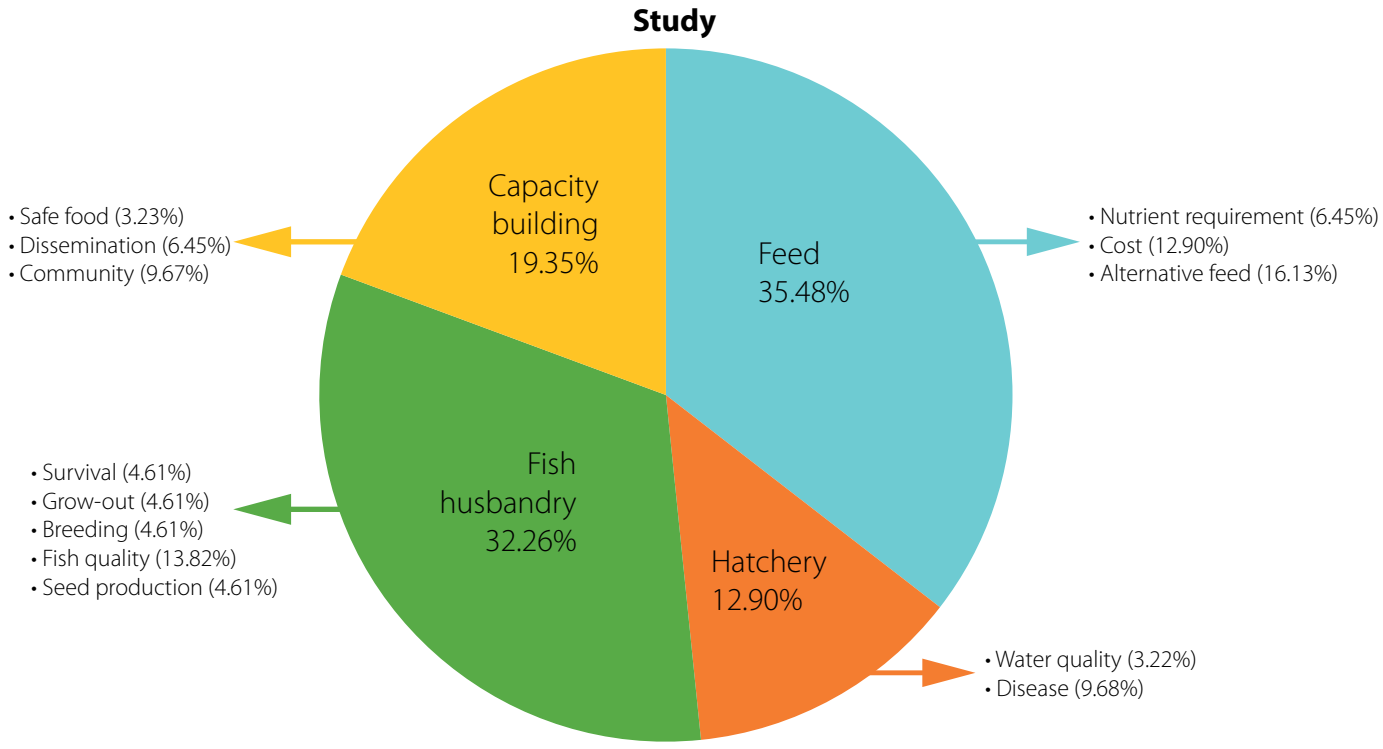

Figure 2. Types of studies and the percentage of interest based on the discussion from the plenary session.

Appendix A. Agenda

Event: Workshop on Development of Bighead Catfish (*Clarias macrocephalus*) Culture for Sustainable Aquaculture in Cambodia

Date: Wednesday, June 28, 2023

Location: RUA, Phnom Penh, Cambodia

Project leader: Dr. Rodrigue Yossa

Partners: CE SAIN, RUA, Kansas State University, Texas A&M University

Funder: Mississippi State University/USAID

Time	Session	Facilitator/Presenter
08:00–08:30	Arrival and registration of participants	
08:30–09:00	Official opening	
	Welcome remarks by a representative of RUA/CE SAIN	Dr. Hok Lyda
	Welcome remarks by the WorldFish country manager, Cambodia	Dr. Sithirith Mak
	Official opening speech by the FiA	Ms. Kaing Kim
09:00–09:10	Presentation 1: Overview of workshop objectives and expected outputs	Dr. Rodrigue Yossa
09:10–09:30	Presentation 2: Bighead catfish project in Cambodia	Mr. Sonoan Kry
09:30–10:00	Break and group photography session	
10:00–10:30	Presentation 3: Wet laboratory built for the bighead catfish project	Mr. Khairul Rizal
10:30–11:00	Presentation 4: First experiment conducted on bighead catfish in the wet laboratory	Mr. Soth Vithun
11:00–12:00	A visit to the wet laboratory at the aquaculture farm of the RUA	Mr. Sonoan Kry and Mr. Soth Vithun
12:00–13:30	Lunch break	
13:30–14:00	Presentation 5: Second experiment ongoing on bighead catfish in the pond	Mr. Soth Vithun
14:00–14:30	Presentation 6: Upcoming fish nutrition experiments	Dr. Aaqillah Amr, Mr. Soth Vithun, Ms. Nurulhuda, Dr. Rodrigue Yossa
14:30–15:00	Tea/coffee break	
15:00–15:30	Breakout session: Identify the research topics of interest for developing BC farming in Cambodia	Dr. Rodrigue Yossa
15:30–16:00	Plenary session: Presentation of group results and discussion	Dr. Rodrigue Yossa
16:00–16:15	Recap and general discussion	Dr. Rodrigue Yossa
16:15–16:30	Closing remarks by CE SAIN representative	Dr. Hok Lyda

Appendix B. List of participants

No.	Name	Position	Organization	Email/Phone
1	Dr. Rodrigue Yossa	Senior scientist, project leader	WorldFish HQ	R.Yossa@cgiar.org
2	Mr. Khairul Rizal Abu Bakar	Research assistant	WorldFish HQ	K.AbuBakar@cgiar.org
3	Mr. Muhammad Rahimi Ramli	Research assistant	WorldFish HQ	M.Ramli@cgiar.org
4	Dr. Aaqillah Amr Mohd Amran	Post-doctoral fellow	WorldFish HQ	A. MohdAmran@cgiar.org
5	Ms. Ning Shahira Sharbini	Research assistant	WorldFish HQ	N.Sharbini@cgiar.org
6	Ms. Chin Hooi Bing	Senior program associate	WorldFish HQ	h.b.chin@cgiar.org
7	Dr. Sithirith Mak	Country manager	WorldFish Cambodia	m.sithirith@cgiar.org
8	Mr. Sok Sao	Research fellow	WorldFish Cambodia	sao.sok@cgiar.org
9	Ms. Ou Phichong	Project manager	WorldFish Cambodia	P.Ou@cgiar.org
10	Ms. Sok Sovanary	HR and admin manager	WorldFish Cambodia	s.sovanary@cgiar.org
11	Ms. Nget Darya	Administrative officer	WorldFish Cambodia	n.darya@cgiar.org
12	Mr. Sean Vichet	Provincial coordinator	WorldFish Cambodia	V.Sean@cgiar.org
13	Mr. Tuy Sinak	Technical officer	WorldFish Cambodia	S.Tuy@cgiar.org
14	Mr. Chan Bunrong	Procurement assistant	WorldFish Cambodia	085666228
15	Ms. San Sokmeas	Emcee	FiA	093553373
16	Mr. Soth Vithun	PhD candidate	RUA	svithun@rua.edu.kh
17	Ms. Kaing Khim	Deputy director general	FiA	017988911
18	Mr. Samorn Channa	Advisor	GIZ	092289485
19	Mr. Vin Chivorn	Team Leader	Hurredo Organization	077359395
20	Mr. Kong Samnang	Officer	Akphivath Neary Khmer Organization	078568704
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23	Mr. Thy Phirom	Marketing manager	Agri-Master Company	kunkirythy2015@gmail.com

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26	Mr. Sron Thavath	Student	RUA	thavathsron@gmail.com
27	Ms. Chhorn Soksan	Officer	RUA	086501820
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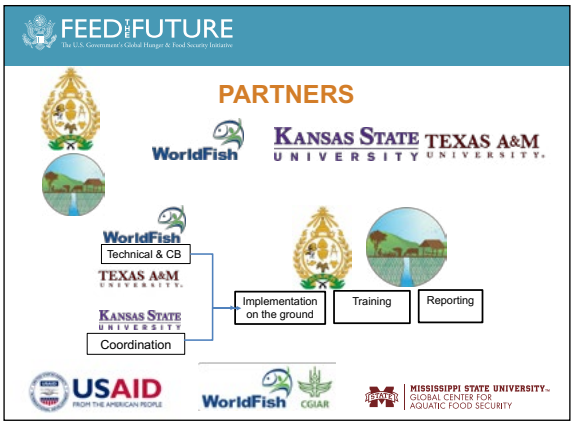
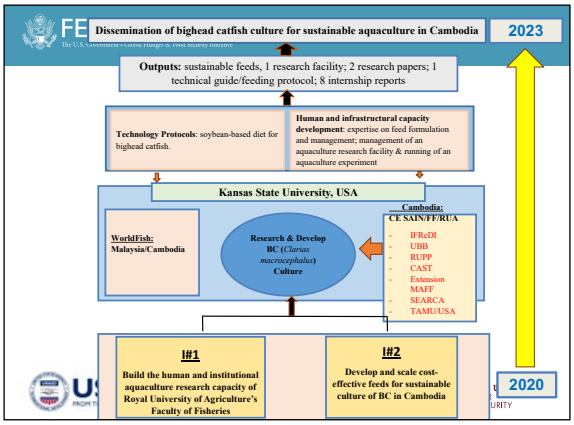
29	Ms. Noeun Simeng	Student	RUA	noeunsimeng@gmail.com
30	Mr. Noeun Panha	Student	RUA	070316095
31	Mr. Sonoan Kry	Project coordinator	CE SAIN	ksonoan@rua.edu.kh
32	Dr. Hok Lyda	Director	CE SAIN	012576594
33	Mr. Tek Sophath	Program manager	CE SAIN	077678983
34	Mr. Vong Bunthoeuk	Communication officer	CE SAIN	015752525
35	Mr. Sam Pheanou	Student	RUA	pheanoukk@gmail.com
36	Mr. Hou Chenda	African walking catfish farmer	N/A	016 498 089
37	Mr. Nak Channa	African walking catfish farmer	N/A	0717997179
38	Mr. Soy Sa	African walking catfish farmer	N/A	077 631001
39	Mr. Khlaing Sokhom	American Soybean Association	CAST	017626522
40	Mr. Suon Sokal	Officer	FARDeC	093870677
41	Mr. Ouk Hak	Deputy head	FiAC, Takeo province	012311012
42	Mr. Kong Sovannara	Head of sector	FiAC, Prey Veng province	0977353132
43	Mr. Cheang Han	Farmer	Prey Veng province	0314773377
44	Mr. Phy Thon	Farmer	Takeo province	077472862
45	Mr. Chet Pisey	Interpreter	Interpreter	010636442
46	Mr. Ly Sao	Interpreter's assistant	First class	070227608

Appendix C. Presentation 1

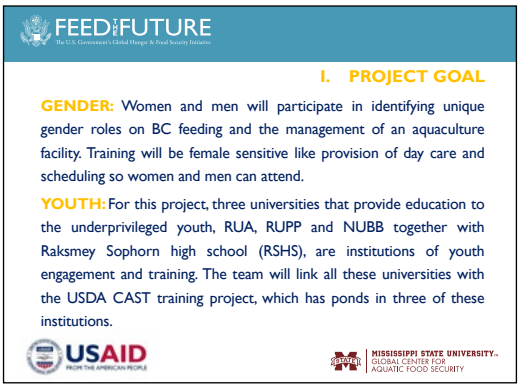
Dr. Rodrigue Yossa

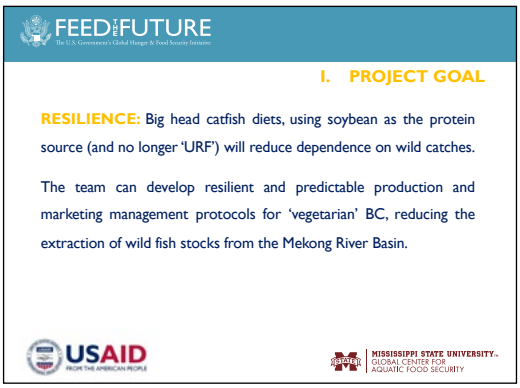


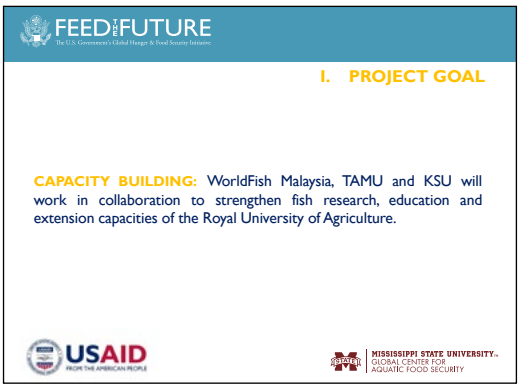


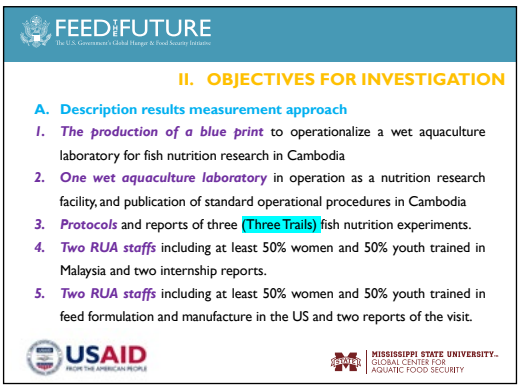
Appendix D. Presentation 2

Mr. Sonoan Kry









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#. One: Strengthening the institutional & human aquaculture research capacity of local institutions in Cambodia.

I. **To purchase and install materials for aquaculture nutrition feed research RUA to operationalize a wet lab.**
   a. Designing and itemizing materials for/to purchase to operationalize a wet lab.
   b. To install the materials to operationalize a wet lab for aquaculture research.

II. **To train the RUA personnel on scientific aquaculture research**
   a. Involving the personnel in the experiments (Wet-Lab)
   b. Training the RUA personnel on running a wet lab in Malaysia
   c. Training the personnel on feed manufacture through a study visit to Texas A&M University (TAMU), USA.

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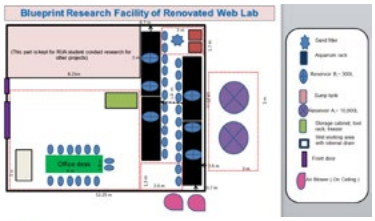
a. Designing and itemizing materials for/to purchase to operationalize a wet lab.

FEED the FUTURE

b. To install the materials to operationalize a wet lab for aquaculture research.



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b. To install the materials to operationalize a wet lab for aquaculture research.

(Team meeting and progress update) (Student Team Setup the Water Tank)

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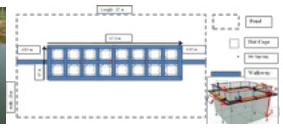
b. To install the materials to operationalize a wet lab for aquaculture research.

(Student Team Setup the Water Tank)

FEED the FUTURE

b. To install the materials to operationalize a Pond "Hapa" for aquaculture research.



(Pond "Hapa" for aquaculture research)

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b. To install the materials to operationalize Fish Feding Machine for aquaculture research.

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II. To train the RUA personnel on scientific aquaculture research

a. Involving the personnel in the experiments (Wet-Lab)

(Students and lecturers came to visit the wetlab)

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II. To train the RUA personnel on scientific aquaculture research

b. Training the RUA personnel on running a wet lab in Cambodia

(Techincail from Malaysia came to train and to setup in Cambodia)

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II. To train the RUA personnel on scientific aquaculture research

b. Training the RUA personnel on running a wet lab in WorldFish Malaysia

(Cambodia Team came to train on Fish Feed Production and sampling the fingerling)

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II. To train the RUA personnel on scientific aquaculture research

c. Training the personnel on feed manufacture Training on Fish Feed Machine (Introduction on machinery, Operation manual, Practice on floating feed production)

Facilitator: Mr. MD MASUM ALI the Bangladesh fish feed engineer.

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I#. Two: To develop and scale cost-effective feeds for sustainable culture of BC in Cambodia.

I. Research contents are: *(PhD Student slide will detail)*

i. Determining protein and lipid (trial 1) requirement levels in grow-out stage under Lab conditions.

ii. Investigate the substitution of fishmeal (FM) and URF protein by soybean meal (SBM) in the diet of BC (trials 2 and 3).

iii. Developing feeding strategies for BC.

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I. Research contents are: *(PhD Student slide will detail)*

i. Determining protein and lipid (trial 1) requirement levels in grow-out stage under Lab conditions.

1. Dean and Lecturer of The faculty of Fishery join the sensory test at the Wetlab.

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I. Research contents are: *(PhD Student slide will detail)*

i. Determining protein and lipid (trial II) requirement levels in grow-out stage in the Pond "Hapa" Progressing

Interns are continuing monitor the fish in the cages and water quality in the pond

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IV. CHALLENGES

1. Covid-19 caused the delay of shipping the materials from Malaysia and led to delay the installation of wet lab.

   Solution: a). closely communicated the supplier; b). sought support from WorldFish Malaysia/Cambodia; c). purchased some alternative supplies locally.

2. Limited supplies and technical expert of the fish feed machine.

   Solution: a). tried to communicate with many suppliers in Cambodia to order from China; b). contacted a consultant from Bangladesh to build capacity of PhD student, RUA personnel and students on the operation of fish feed machine.

3. Limited standard of ingredients to produce the fish feed.

   Solution: a). sought advice from technical advisory board to revise the feed formula to fit with local availabilities; b). contacted local suppliers including feed mill to supply the required incredients

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V. RECOMMENDATION

1. Faculty of Fisheries and Aquaculture, WorldFish, and CE SAIN should continue support PhD student to complete his research to be used as the reference for researchers and students to continue researching on feed formulation on bighead catfish.
2. Researchers and relevant stakeholders should continue to improve the quality and quantity of fingerling and feed to increase the production of bighead catfish in Cambodia.
3. Fish disease and bio-security need to be consider, while aquaculture sub-sector in Cambodia is increasing.

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Appendix E. Presentation 3

Mr. Khairul Rizal Abu Bakar

RUA Bighead Catfish Project Wet Laboratory

Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN), Royal University of Agriculture (RUA), Cambodia

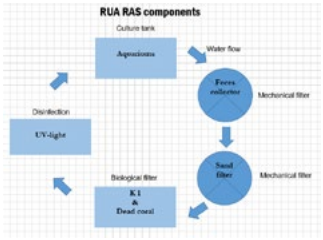
28 June 2023

Recirculating Aquaculture System

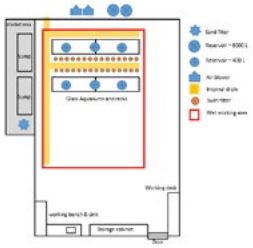
- *FAO (The Food and Agriculture Organisation of United Nations)* described:
  - aquaculture as the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants which may implies some form of intervention in the rearing process to enhance production
- Recirculation aquaculture is basically a technology for farming fish or other aquatic organism by reusing water in the production
- Mechanical and biological filtration to remove fecal material, suspended debris for water quality control

RAS components

- Culture tanks
  - Aquarium
- Mechanical filter
  - Swirl/Feces collector
  - Sand Filter
- Biological filter
  - Kaldnes K1 filter media
- Water treatment area-UV sterilizer



RUA Wet Laboratory Blue Print (Suggestion)

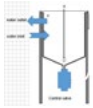


Culture Tank

- 40 glass aquariums
- Size 0.9L x 0.5W x 0.4H ~150L water holding capacity per aquarium
- Water input by gravity with aeration

Primary Mechanical Filter

- 40 Swirl filter/Feces collector made from fiberglass
- 70-90% efficiency of collecting waste
- Schedule cleaning to maximize waste removal and minimize water loss
- Digestibility experiment



Secondary Mechanical Filter

- Waterco S800 Sand filter
- To collect waste pass through feces collector
- Fine sand as the medium filter
- Other filter media available in the market
  - Pearl glass bead filter
  - Zeolite media filter (ammonia reducing agent)

Biological Filter

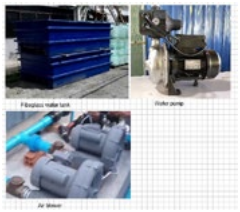
- **Convert dissolved ammonia derived from fish metabolic byproduct to nitrite and nitrate**
- **K1 moving bed bioreactor**
- **K1 to host nitrifying bacteria**
- **nitrifying process convert ammonia to nitrite and nitrate**
- **rapid aeration to enhance oxidizing process by bacteria, prevent K1 clogging**
- **estimated 1m^3 K1 = 800m^2 surface area, removed 456g NH_3**
- **dead coral as pH buffer (~pH 7-8) to maximize oxidation process**

Water treatment

- **Waterco UV-sterilizer**
- **Reduce the risk of pathogen**
- **Stationed after filtration section**

Other instruments

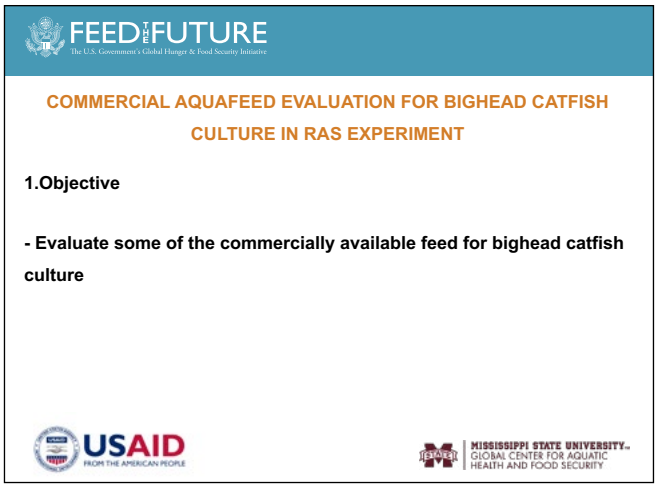
- 2 units water pumps for water flow
  - One pump to the sand filter
  - One pump sending water to reservoir for gravity flow into aquariums
- 2 units fiberglass tank (8L x 4W x 4H ft) to facilitate mechanical and biological filtration
- 2 units air blower running alternately to provide aeration for aquariums and K1
- 1 unit water pump for general purpose usage such as for aquarium maintenance and cleaning, sampling fish

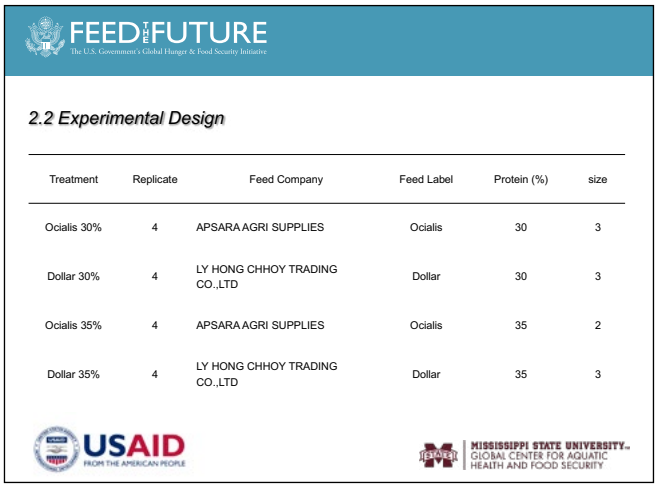


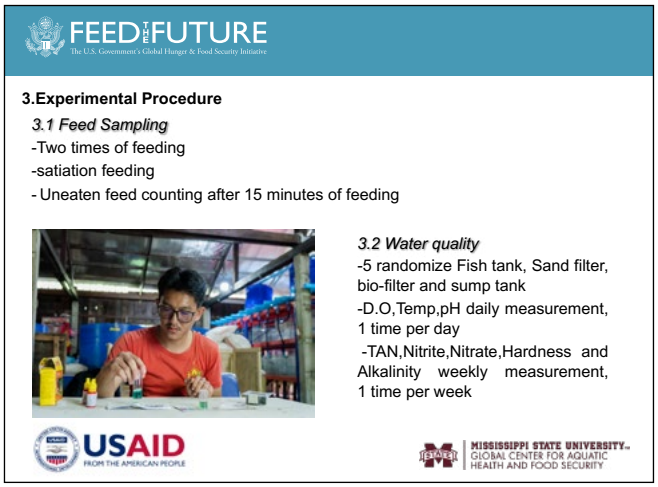
Thank you

Appendix F. Presentation 4

Mr. Soth Vithun







3. DATA ANALYSIS

4.SUMMARY RESULT

4.1 Growth Performance and Somatic Index

Variable	Variable	ILW (g)	FLW (g)	DWG (g/day)	SGR (%)	FCR	FR (%)	Male (%) GSI	Male (%) HSI	Male (%) VSI	Female (%) GSI	Female (%) HSI	Female (%) VSI
Main effect	30 %	85.48	102.21^{b}	0.20^{b}	0.21^{b}	2.88	0.72^{b}	0.32	0.43	0.29	6.81	0.36	0.07
Protein	35 %	86.43	123.38^{a}	0.44^{a}	0.42^{a}	1.73	0.83^{a}	0.34	0.81	0.30	6.70	0.38	0.13
Main effect	Ocialis	86.54	114.14	0.33	0.34	2.16	0.78	0.35	0.79	0.27	7.24	0.36	0.09
Feed Label	Dollar	85.37	111.45	0.31	0.32	2.04	0.77	0.31	0.43	0.32	6.32	0.38	0.10
Interaction effect													
Ocialis	30 %	86.85	108.16^{a}	0.25^{b}	0.26^{bc}	2.51	0.77^{b}	0.31	0.47	0.36^{ab}	6.82	0.38^{ab}	0.08
Ocialis	35 %	86.23	120.11^{b}	0.40^{a}	0.39^{ab}	1.74	0.79^{b}	0.38	1.11	0.17^{c}	7.66	0.35^{ab}	0.10
Dollar	30 %	84.12	96.25^{d}	0.14^{b}	0.16^{c}	3.52	0.67^{c}	0.32	0.39	0.21^{bc}	6.81	0.34^{b}	0.05
Dollar	35 %	86.62	126.65^{a}	0.48^{a}	0.45^{a}	1.72	0.87^{a}	0.29	0.48	0.45^{a}	5.85	0.41^{a}	0.15
P-Value	Feed Label	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Main effect	Protein	NS	<0.000	<0.000	<0.000	NS	<0.000	NS	NS	NS	NS	NS	NS
Interaction Main effect	Feed Label x Protein	NS	<0.000	0.064	NS	NS	<0.000	NS	NS	<0.000	NS	0.043	NS

4.2 water quality

Description	Fish Tank	Sand filter	Bio-filter	Sump tank
D.O (mg/L)	6.15	5.92	6.71	6.15
Temperature (0C)	30.54	30.82	30.76	30.81
pH	7.72	7.74	7.72	7.73
TAN (mg/L)	0.50	0.23	0.30	0.14
Nitrite (mg/L)	0.18	0.29	0.21	0.17
Nitrate (mg/L)	67.08	68.75	69.58	62.92
Hardness (d0GH)	15.13	15.25	15	14.75
Alkalinity (d0KH)	9.14	9.33	8.92	9.25

5.CONCLUSION

Base on result from this study that can concluded the Feed branch is non-significant in fish growth, FCR and somatic index but protein 35% can promote for bighead catfish culture because it improve on growth performance and FCR.

Thank you so much!!!!!

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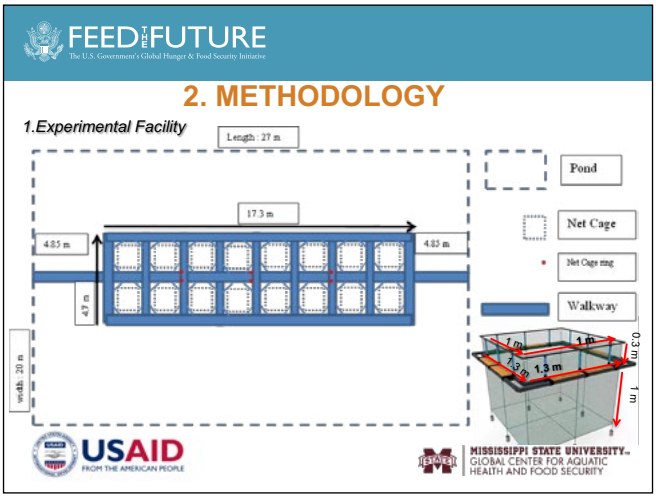
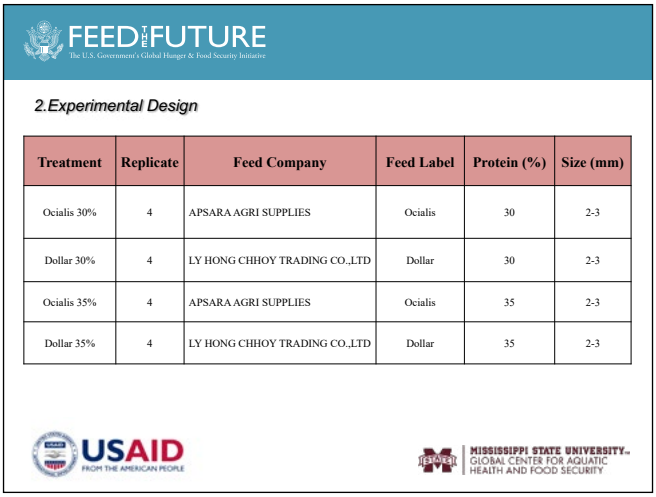
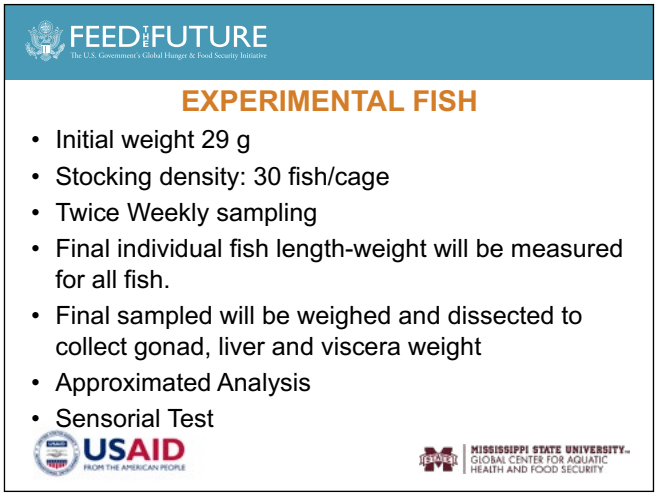
Appendix G. Presentation 5

Mr. Soth Vithun





Treatment	Replicate	Feed Company	Feed Label	Protein (%)	Size (mm)
Ocialis 30%	4	APSARA AGRI SUPPLIES	Ocialis	30	2-3
Dollar 30%	4	LY HONG CHHOY TRADING CO.,LTD	Dollar	30	2-3
Ocialis 35%	4	APSARA AGRI SUPPLIES	Ocialis	35	2-3
Dollar 35%	4	LY HONG CHHOY TRADING CO.,LTD	Dollar	35	2-3



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EXPERIMENTAL FEED

- Two companies with 2 proteins
- 3 times of feeding per day
- Uneaten feed is calculated by pellet counting after 15 minute
- Approximated Analysis
- Feed Intake,FCR,PER will be calculation

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WATER QUALITY

- Water quality measure on D.O,pH,Temperature, water tranperancy (sechi-disk), TAN,Nitrite,Nitrate, Hardness and Alkalinity
- Water quality measure in each 5 randomize cages and pond
- Daily measurement is D.O,pH,Temperature, 2 time per day
- weekly measurement is water tranperancy (sechi-disk), TAN,Nitrite,Nitrate, Hardness and Alkalinity, 1 time per week

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Water quality

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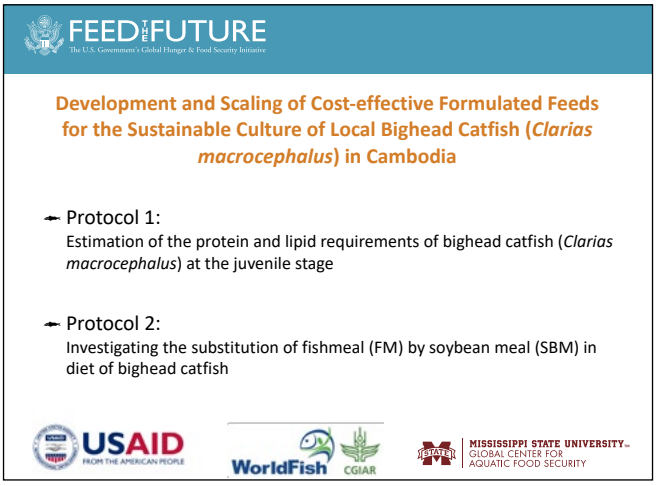
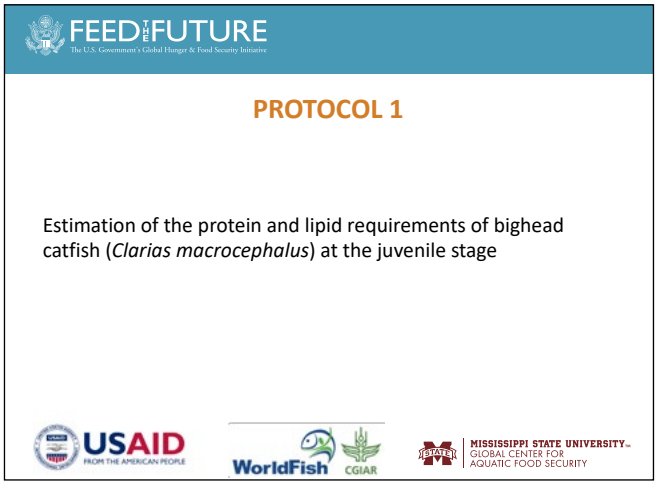
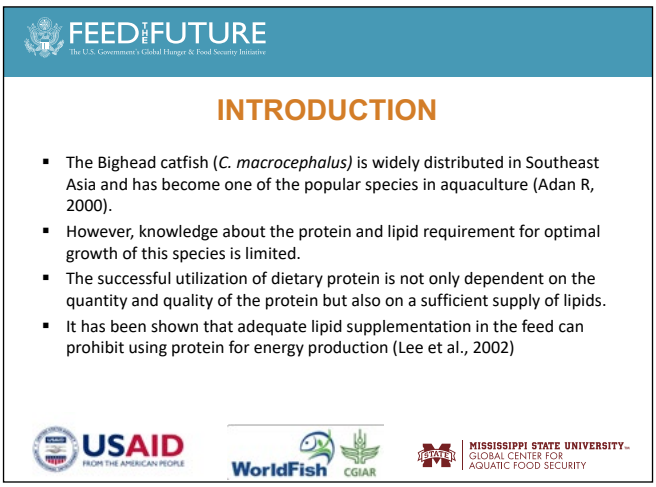
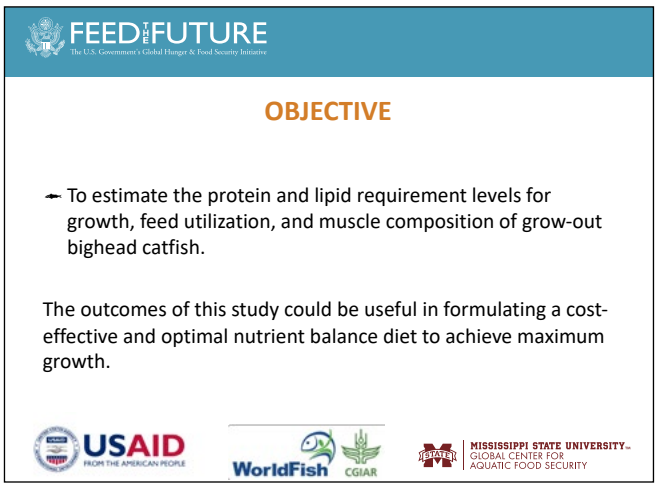
Appendix H. Presentation 6

Dr. Aaqillah Amr Mohd Amran









MATERIALS AND METHODS

Experimental Design

- An 8-week experiment will be conducted at the Aquaculture facility at RUA
- 4 × 3 factorial design

Protein level (30, 35, 40, and 45%) × lipid level (6, 8, and 10%) = 12 treatments, 3 replicates

∴ 36 of 180L glass aquaria connected to RAS will be used

MATERIALS AND METHODS

Experimental Diets

- Twelve diets will be manufactured consisting of four protein levels (30, 35, 40, and 45%) and three lipid levels (6, 8, and 10%)
- A 20 kg of 2.0 mm pellet size and 20 kg of 3.0 mm pellet size to make a total of 40 kg of each diet
- Assuming that
  1. Initial average weight = 15 g; Final average weight = 100 g
  2. No mortality
  3. FCR of 1.5.

	Experimental feed (Protein-Lipid)											
Ingredients	30P-6L	30P-8L	30P-10L	35P-6L	35P-8L	35P-10L	40P-6L	40P-8L	40P-10L	45P-6L	45P-8L	45P-10L
Fish meal, Danish, 70% CP	20	20	20	28	28	28	36	36	36	43.5	44	44
Soybean meal, 48% CP	25	25	25	25	25	25	25	25	25	25	25	25
Corn meal, Brazil	18	18	16	17	13	10	14.5	8	8	8	8	8
Rice bran, SE Asia	14	14	15	9	11	12.5	7	8.5	9	4.2	6.25	6
Wheat, flour	17	15	14	15	15	15	12	15	12.5	14	10	8
Canola oil	1	3	5	1	3	4.5	0.5	2.5	4.5	0.3	1.75	4
Fish oil, Pangasius (basa)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate, DCP, CaHPO4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Mineral premix IAFFD Standard, FW fish grower, 0.25%	1	1	1	1	1	1	1	1	1	1	1	1
Rowimix-stay-C 25, ascorbyl-monophosphate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin premix IAFFD Standard, FW fish grower, 0.5%	1	1	1	1	1	1	1	1	1	1	1	1
Soy lecithin	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
L-Lysine	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	100	100		100	100	100	100	100	100	100	100	100
DM%	74.97	76.95	78.08	77.02	77.29	77.49	79.94	77.58	80.01	78.49	82.22	84.23
Ash%	8.34	8.34	8.24	8.94	8.73	8.57	9.57	9.13	9.16	9.79	9.95	9.95
GE MJ/kg	14.64	15.41	16.06	15.27	15.79	16.18	16.00	16.07	16.93	16.02	17.04	17.86
DE MJ/kg	11.30	12.04	12.72	12.02	12.67	13.15	12.82	13.18	13.98	13.18	14.06	14.86
CP%	30.18	30.18	30.14	35.18	35.09	35.03	40.40	40.06	40.12	44.87	45.46	45.43
Dig CP%	26.24	26.24	26.21	30.67	30.60	30.55	35.28	35.00	35.05	39.25	39.74	39.72
Lipid%	6.00	7.98	9.98	6.26	8.29	9.80	6.26	8.15	10.17	6.29	7.97	10.17
Fibre%	3.27	3.27	3.37	2.63	2.82	2.96	2.35	2.43	2.50	1.90	2.17	2.13

MATERIALS AND METHODS

Experimental Fish

- Mixed sex of grow-out bighead catfish at initial body weight ~15 g will be used.
- 70 fish will be randomly selected and stocked into each of the aquariums.
- Samplings will be conducted biweekly (Week 2, 4, and 6) and at the end of the experiment (Week 8)
- Fish will be hand fed three times daily to apparent satiation and the fish behavior will be monitored.

MATERIALS AND METHODS

- Any uneaten feed will be collected from the tank and will be kept frozen (-20 °C) until the end of the experiment for the apparent feed intake
- The chemical analysis of the collected experimental feed and the fish sample (Initial and final) will be performed after the experiment is completed.

MATERIALS AND METHODS

Sample Collection and Analysis

Feed sample	Initial Fish	Final Fish (per tank)
500 g/samples * 12 feeds = 12 samples	2*2 pools = 4 samples	*2 fish pool x 36 tanks = 72 samples*

Initial fish	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Amino acid profile	Fatty acid profile	Individual weight (g)	Total length (cm)	Standard length	Liver weight (g)	Gonad weight (g)	Viscera weight (g)	
Final fish	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Amino acid profile	Fatty acid profile	Individual weight (g)	Total length (cm)	Standard length	Liver weight (g)	Gonad weight (g)	Viscera weight (g)	No of fish each tank
Feed/ diets	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Amino acid profile	Fatty acid profile							
Biweekly sampling	Bulk Fish weight each tank	No of fish in each tank	Weight (g)												
Daily	Water quality	Feed intake	Mortality												

PROTOCOL 2

Investigating the substitution of fishmeal (FM) with soybean meal (SBM) in the diet of bighead catfish, *Clarias macrocephalus*

INTRODUCTION

- SBM is the most common plant protein ingredient used in aquafeed for its availability, lower cost, ideal amino acids profile, and high protein content
- The presence of anti-nutritional factors i.e. phytic acid
- Mono gastric fishes hardly metabolize phytate effectively due to insufficient levels phytase; dietary phosphorus cannot be utilized properly and will be excreted through their feces.
- Phytase help catalyze phytate hydrolysis and phosphorus to make it available for absorption, thereby improving mineral availability, and protein digestibility

OBJECTIVE

To estimate the effect of FM replacement with SBM and the efficacy of adding phytase in the diet for bighead catfish.

MATERIALS AND METHODS

Experimental Design

- A 12-week experiment will be conducted at the Aquaculture facility at RUA
- A 5 × 2 factorial experiment
  - Soybean inclusion (0, 25, 50, 75, and 100%) × dietary phytase (addition or non-addition of phytase 2500 FTU/kg)
  - 10 treatments, 4 replicates, thus 40 glass aquaria (180 L) will be used for the experiment with swirl separators attached for fecal collection
  - Daily fecal material collection from each tank will be conducted during the last two weeks of the experiment, to determine digestibility.

MATERIALS AND METHODS

Experimental Diets

- Ten diets will be prepared; five levels of fishmeal replacement with SBM, with or without additional phytase
- 2% acid-insoluble ash as an inert marker
- No addition of inorganic phosphorus to optimize phytate hydrolysis
- A total of 45 kg of each diet will be prepared assuming that
  - Initial average weight = 50 g; Final average weight = 300 g
  - No mortality
  - FCR of 1.5

MATERIALS AND METHODS

Experimental fish

- 30 mixed-sex bighead catfish fish (~ 50 g) will be randomly distributed
- Fish will be hand-fed three times per day to apparent satiation
  - All uneaten feed will be collected from the tank until the end of the experiment.
  - Two weeks before the experiment ended, fecal material will be collected every day for a digestibility study.
  - Analysis of the pellet used in the experiment and whole fish (Initial and final) will be performed after the experiment is completed.

MATERIALS AND METHODS

Sample collection and analysis

Diets	Initial Fish	Final Fish (per tank)
500 g/samples = 10 samples	2*2 pools	2 fish pool x 40 tanks = 80 samples

Initial fish	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Amino acid profile	Fatty acid profile	Individual weight (g)	Total length (cm)	Standard length	Liver weight (g)	Gonad weight (g)	Viscera weight (g)		
Final fish	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Phosphorus content	Amino acid profile	Fatty acid profile	Individual weight (g)	Total length (cm)	Standard length	Liver weight (g)	Gonad weight (g)	Viscera weight (g)	No of fish each tank
Feed/ diets	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Phosphorus content	Amino acid profile	Fatty acid profile	Weight (g)						
Fecal material	Dry matter	Total ash	Crude fat	Crude protein	Crude fiber	Gross energy	Phosphorus content	Amino acid profile	Fatty acid profile							
Biweekly sampling	Bulk Fish weight each tank	No of fish in each tank														
Daily	Water quality	Feed intake	Mortality													

Kansas State University

Collaborative Research on Sustainable Intensification

Thank You

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Appendix I. Breakout session

Development of Bighead Catfish (*Clarias macrocephalus*)
Culture for Sustainable Aquaculture in Cambodia

Group number.:

R&D topics of interest	Justifications	Ranking
		%
Total		

About WorldFish

WorldFish is a leading international research organization working to transform aquatic food systems to reduce hunger, malnutrition, and poverty. It collaborates with international, regional, and national partners to co-develop and deliver scientific innovations, evidence for policy, and knowledge to enable equitable and inclusive impact for millions who depend on fish for their livelihoods. As a member of CGIAR, WorldFish contributes to building a food- and nutrition-secure future and restoring natural resources. Headquartered in Penang, Malaysia, with country offices across Africa, Asia, and the Pacific, WorldFish strives to create resilient and inclusive food systems for shared prosperity.

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