

# Manufacturing Tilapia Feed

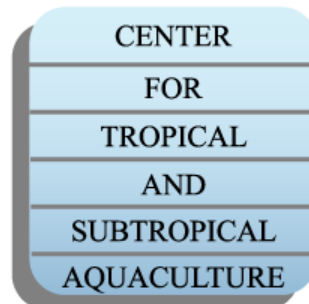
## A Manual Using Local Feedstuff Resources for Fish Farming in American Samoa

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# INTRODUCTION

In American Samoa, tilapia farmers currently rely on costly, imported Asian fish feed which makes their tilapia production costs extremely high. However, there is the potential for farmers in American Samoa to develop and utilize local feedstuff resources to manufacture their own tilapia feeds. Using generic tuna fishmeal and tuna oil from the local tuna cannery, along with locally available starch ingredients, farmers can manufacture fish feeds (adult and children's method) that meet the nutritional needs of tilapia, thereby creating the potential for a sustainable fish farming industry in American Samoa.

This tilapia feeds manual provides the basic information on nutritional value of animal and plant products or byproducts available locally in American Samoa, as well as the basal formulas using these ingredients (Table 1-12). Information in this manual includes the basic feed processing techniques (Appendix A-F), a guide for equipment procurement and a CD. The CD contains the following: Particle Size Distribution Excel files (both Full Range and Short Range versions) with data sheets, an example calculation sheet, and calculation sheets. PDF files of the method flowcharts from the appendices are also included. Also included are: Kansas State Feed Science publications on: 1) Sampling: Procedures for Feed, 2) Testing Mixer Performance, 3) Evaluating Particle Size, 4) Evaluating Feed Components and Finished Feeds, and 5) The Effects of Diet Particle Size on Animal Performance.

Table 1. Tilapia diet formulation for the Adult and Children's Methods. Values are on an "As Fed" Basis.

Adult Method		Children's Method	
Ingredient	%	Ingredient	
Multipurpose Wheat Flour	40.4	Multipurpose Wheat Flour	cans <sup>3</sup> 4
Generic Tuna Fishmeal	26.9	Generic Tuna Fishmeal	cans <sup>3</sup> 3
Cooked Local Starch <sup>1</sup>	19.2	Cooked Local Starch <sup>1</sup>	can <sup>3</sup> 1
Plant Oil	1.2	Plant Oil	spoonful* 5
Vitamin Mix	0.4	Vitamin Mix	packet* 1
Trace Min Mix	0.4	Trace Min Mix	packet* 1
Water <sup>2</sup>	11.5	Water <sup>2</sup>	can <sup>3</sup> 2
	100	Yield kilograms	2 - 2.3

<sup>1</sup>Cooked Local Starch is ulu or fa'i or taro, etc. Assumes about 60% moisture.

<sup>2</sup>Brings Water content of diet up to 30%

<sup>3</sup>Using an 18.5 oz. soup can. This method can be scaled to any size using the ratio of ingredients provided.

\*Spoonful=teaspoon

\*Packet=4g/kg feed (see Tables 11 & 12)

Table 2. Local feedstuff resources for aquatic feed development in American Samoa.

Local Feedstuffs <sup>1</sup>	Quantity Available (lbs) <sup>2</sup>
Tuna meal from local cannery <sup>3</sup>	15,600,000
Bananas (Fa'i Palagi) harvested for sale	3,766,815
Bananas (Fa'i Palagi) harvested for home use	2,926,810
Other varieties of banana harvested for sale	1,726,845
Other varieties of banana harvested for home use	3,874,750
Breadfruit (Ulu) harvested for sale	252,375
Breadfruit (Ulu) harvested for home use	3,140,728
Fa'i palagi (banana) leaf and stalk <sup>4</sup>	13,387,088
Other varieties of banana leaf and stalk <sup>4</sup>	11,203,190
Taro harvested for sale	4,253,680
Taro harvested for home use	9,088,374
Cassava harvested for sale	169,250
Cassava harvested for home use	776,071

<sup>1</sup>Local plant feedstuffs were all cooked prior to use.

<sup>2</sup>Data, except for fishmeal, banana leaf and banana stalk, from the USDA American Samoa 2007 Agricultural Census.

<sup>3</sup>Quantity estimated from daily generic tuna fishmeal production, C. Lim. 2007. American Samoa Trip Report, December 8 – 16, 2007.

<sup>4</sup>Data for banana leaf and stalk estimated from banana production quantities (E. Temple, personal communication)

Table 3. Proximate composition and energy values of local feedstuffs of American Samoa and two tilapia diets. Values are on a “Dry Matter” Basis. Plant ingredient samples were collected by students at American Samoa Community College.

Ingredients	Ash	Crude Protein	Crude Fat	Crude Fiber	NFE <sup>a</sup>	Gross Energy
		(%)				(cal/g)
Giant Cavendish Banana with Skin <sup>b</sup>	5.46	2.53	2.04	3.01	86.96	4146
Giant Cavendish Banana w/out Skin <sup>b</sup>	3.11	2.98	0.16	0.95	92.80	4101
Bluggoe Banana w/out Skin <sup>b</sup>	2.30	1.90	0.24	1.02	94.56	4129
Breadfruit with Skin <sup>b</sup>	3.15	3.06	1.36	3.42	89.00	4161
Breadfruit w/out Skin <sup>b</sup>	3.09	1.94	1.10	3.46	90.41	4163
Banana Leaf <sup>b</sup>	9.36	10.56	6.55	23.77	49.76	4684
Fa'i (banana) Stalk <sup>b</sup>	17.06	3.30	1.79	29.17	48.68	3490
Taro w/out Skin <sup>b</sup>	2.41	3.67	0.24	2.04	91.64	4112
Taro with Skin <sup>b</sup>	2.29	3.59	0.91	3.87	89.34	4213
Taro Skin <sup>b</sup>	9.01	4.92	0.84	10.12	75.12	4053
Cassava Flour	1.65	3.39	0.01	1.68	93.27	4014
All-purpose Flour	0.74	14.02	0.64	0.33	84.27	4418
Generic Tuna Fishmeal	20.98	63.20	14.24	0.97	0.61	5052
Tilapia Diets						
Adult Method	8.29	30.65	6.37	0.65	47.28	4636
Children's Method	7.01	25.47	7.15	1.09	54.01	4641

<sup>a</sup>NFE: Nitrogen Free Extract (g/100g DM) calculated by 100-(Ash + Crude Protein + Crude Lipid + Crude Fiber=carbohydrate fraction)

<sup>b</sup>Ingredients were cooked prior to analysis and use.

Table 4. Mineral contents of local feedstuffs of American Samoa and two tilapia diets. Values are on a “Dry Matter” Basis.

Ingredients	P	K	Ca	Mg	Na	B	Cu	Fe	Mn	Zn
	(% )					(mg/kg)				
Giant Cavendish Banana with Skin*	0.14	2.71	0.11	0.15	0.02	10	5	56	5	9
Giant Cavendish Banana w/out Skin*	0.10	1.56	0.03	0.13	0.01	5	5	29	2	8
Bluggoe Banana w/out Skin*	0.13	1.14	0.03	0.12	0.01	3	3	26	2	13
Breadfruit with Skin*	0.14	1.52	0.09	0.09	0.02	5	4	43	3	4
Breadfruit w/out Skin*	0.14	1.51	0.08	0.08	0.02	5	4	65	3	5
Banana Leaf*	0.32	3.34	0.42	0.41	0.01	13	6	64	214	10
Fa'i (banana) Stalk*	0.75	8.00	0.43	0.22	0.01	13	3	33	39	5
Taro w/out Skin*	0.09	1.07	0.11	0.08	0.01	4	5	26	7	4
Taro with Skin*	0.07	0.30	0.33	0.11	0.06	4	3	3239	66	15
Taro Skin*	0.12	1.25	0.55	0.20	0.28	9	9	11300	314	34
Cassava Flour	0.15	0.80	0.04	0.06	0.01	3	2	8	4	14
All-purpose Flour	0.16	0.17	0.03	0.05	0.01	3	3	59	11	11
Generic Tuna Fishmeal	3.98	0.46	6.39	0.23	1.45	5	5	324	5	123
Tilapia Diets										
Adult Method	1.40	0.29	2.41	0.11	0.52	3	7	276	36	169
Children's Method	1.11	0.30	1.83	0.10	0.43	2	20	176	33	147

Mineral abbreviations: P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium, B = Boron, Cu = Copper, Fe = Iron, Mn = Manganese, Zn = Zinc.

\*Ingredients were cooked prior to analysis and use. Cook taro in cast iron pot.

Table 5. Amino acid profile of generic tuna fishmeal and two tilapia diets. Values are on an “As Fed” Basis.

Amino Acids	Generic Tuna Fishmeal (g/100g)	Adult Method (g/100g)	Children's Method (g/100g)
Non-essential Amino Acids			
Alanine	4.50	1.74	1.34
Aspartic acid + Asparagine	4.01	2.51	1.91
Cysteine	0.90	0.19	0.36
Glutamic acid + Glutamine	5.06	4.65	4.05
Glycine	4.00	1.70	1.39
Proline	2.89	1.89	1.65
Serine	2.48	1.17	0.99
Tyrosine	2.53	0.88	0.75
Taurine	0.57	0.20	0.15
Essential Amino Acids			
Arginine	4.52	1.91	1.54
Histidine	2.17	0.92	0.74
Isoleucine	2.45	1.21	1.00
Leucine	3.94	1.97	1.66
Lysine	2.78	1.51	1.29
Methionine	2.02	0.71	0.58
Phenylalanine	1.59	1.15	1.00
Threonine	3.16	1.40	1.15
Tryptophan	0.00	0.00	0.00
Valine	3.31	1.51	1.21
Non-essential Amino Acids subtotal	26.37	14.73	12.43
Essential Amino Acids subtotal	25.94	12.29	10.17
Total Amino Acids	52.31	27.02	22.60

Table 6. Fatty acid profile of generic tuna fishmeal and two tilapia diets. Values are on an “As Fed” Basis.

Fatty Acids	Code	Generic	Adult	Children's
		Tuna Fishmeal g/kg	Method g/kg	Method g/kg
Tetradecanoic (Myristic)	C14:0	3.02	0.11	0.95
Pentadecanoic	C15:0	1.12	0.04	0.37
Hexadecanoic (Palmitic)	C16:0	30.42	1.34	14.88
Hexadecenoic (trans-Palmitilaidic)	C16:1n-9	0.09	0.01	0.11
Hexadecenoic (Palmitoleic)	C16:1n-7	4.22	0.14	1.31
Hexadecadienoic	C16:2n-4	0.07	0.02	0.21
Hexadecatrienoic	C16:3n-4	0.15	0.00	0.32
Heptadecanoic	C17:0	2.17	0.07	0.64
Octadecanoic (Stearic)	C18:0	13.43	0.43	3.96
Oleic acid	C18:1n-9	16.07	0.82	11.23
Octadecenoic	C18:1n-7	1.79	0.10	0.86
Octadecadienoic (Linoleic)	C18:2n-6	0.13	1.04	16.35
Octadecatrienoic (Gamma Linolenic)	C18:3n-6	0.56	0.02	0.00
Octadecatrienoic	C18:3n-4	0.26	0.01	0.00
Linolenate (ALA)	C18:3n-3	0.50	0.11	1.72
Octadecatetraenoic (Steradonic)	C18:4n-3	0.65	0.02	0.21
Eicosanoic (Arachidic)	C20:0	0.18	0.02	0.43
Eicosenoic	C20:1n-9	0.54	0.06	0.17
Eicosatrienoic	C20:3n-3	0.09	0.09	0.09
Eicosatetraenoic	C20:4n-6	0.30	0.00	0.70
Eicosatetraenoic (Arachidonic)	C20:4n-3	0.00	0.02	0.12
Eicosapentaenoate (EPA)	C20:5n-3	7.11	0.19	1.44
Docosapentaenoate	C22:5n-6	2.34	0.07	0.34
Docosapentanoic	C22:5n-3	4.57	0.12	0.55
Docosahexaenoate (DHA)	C22:6n-3	17.84	0.87	4.45
Lignocerate	C24:0	1.39	0.05	0.00
Nervonate	C24:1	0.21	0.00	0.00
Identified		109.24	5.77	61.42
Unidentified		17.38	0.25	1.00
Total Fatty Acids		126.62	6.02	62.41

Table 7. Pellet water stability of tilapia diet pellets after immersion in fresh water.

	Leaching Duration	
	15 min	30 min
Adult Method (%)	96.5 ± 1.0	94.9 ± 0.6
Children's Method (%)	94.0 ± 0.9	93.0 ± 1.0

N = 3. Within each leaching period, pellet water stability was not significantly different between the two diets, determined by Fisher's LSD test ( $p > 0.05$ ).

Table 8. Nutrient requirements of tilapia and nutritional profiles of tilapia diets. Values are on a Dry Matter Basis.

	NRC 2011*	Am. Samoa Adult Method	Am. Samoa Children's Method
<b>Typical Energy and Protein Concentrations<sup>a</sup></b>			
Digestible Energy (kcal/kg diet)	3400	NT	NT
Gross Energy (kcal/kg diet)		4636	4641
Digestible Protein (%)	29	NT	NT
Crude Protein (%)		30.7	25.5 - 29.7
Crude Lipid (%)		6.37	7.15
<b>Nutrient Requirements</b>			
<b>Amino Acids (%)</b>			
Arginine	1.2	2.05	1.63
Histidine	1	0.98	0.78
Isoleucine	1	1.30	1.05
Leucine	1.9	2.11	1.75
Lysine	1.6	1.62	1.36
Methionine	0.7	0.76	0.61
Methionine + cystine	1	NT	NT
Phenylalanine	1.1	1.23	1.05
Phenylalanine + tyrosine	1.6	NT	NT
Threonine	1.1	1.50	1.21
Tryptophan	0.3	0.00	0.00
Valine	1.5	1.62	1.28
Taurine	NT	0.21	0.15
<b>Fatty Acids (%)</b>			
18:3n-3	NT	1.87	2.91
n-3LC-PUFA (20-5n-3 and/or 22-6n-3)	R	18.89	9.97
18:2n-6	0.5 -1.0	18.51	27.65
<b>Cholesterol (%)</b>			
	NT	NT	NT
<b>Phospholipids (%)</b>			
	NT	NT	NT
<b>Macrominerals (%)</b>			
Calcium	R/0.7 <sup>b</sup>	2.41	1.83
Chlorine	0.15	NT	NT
Magnesium	0.06	0.11	0.10
Phosphorus	0.4	1.40	1.11
Potassium	0.20-0.30	0.29	0.30
Sodium	0.15	0.52	0.43

NR = not required under practical conditions (e.g. diets containing ingredients from marine and land animal protein and fish oil and water of at least medium hardness)

NT = Not Tested

R = Required in diet but quantity not determined

\*Committee on the Nutrient Requirements of Fish and Shrimp, Board on Agriculture and Natural Resources, Division on Earth and Life Studies, National Research Council of the National Academies. Nutrient Requirements of Fish and Shrimp. 2011. The National Academies Press, Washington D. C. 376pp.

<sup>a</sup> Typical digestible energy and digestible crude protein concentrations (digestible N x 6.25) in commercial diets

<sup>b</sup> Dietary requirement in absence of waterborne calcium.

Table 8. (con't) Nutrient requirements of tilapia and nutritional profiles of tilapia diets. Values are on a Dry Matter Basis.

	NRC 2011*	Am. Samoa Adult Method	Am. Samoa Children's Method
<b>Microminerals (mg/kg)</b>			
Boron	NT	3	2
Copper	5	7	20
Iodine	NT	NT	NT
Iron	85	276	176
Manganese	7	36	33
Selenium	NT	NT	NT
Zinc	20	169	147
<b>Fat-soluble Vitamins<sup>c</sup></b>			
A (mg/kg)	1.8	NT	NT
D (µg/kg)	9	NT	NT
E (mg/kg)	60	NT	NT
K (mg/kg)	NT	NT	NT
<b>Water-soluble Vitamins (mg/kg)</b>			
Thiamin	NT	NT	NT
Riboflavin	6	NT	NT
Vitamin B6	15	NT	NT
Pantothenic Acid	10	NT	NT
Niacin	26	NT	NT
Biotin	0.06	NT	NT
Vitamin B12	NR	NT	NT
Folacin	1	NT	NT
Choline <sup>d</sup>	1000	NT	NT
Myoinositol <sup>d</sup>	400	NT	NT
Vitamin C <sup>e</sup>	20	NT	NT

NR = not required under practical conditions (e.g. diets containing ingredients from marine and land animal protein and fish oil and water of at least medium hardness)

NT = Not Tested

\* Committee on the Nutrient Requirements of Fish and Shrimp, Board on Agriculture and Natural Resources, Division on Earth and Life Studies, National Research Council of the National Academies. Nutrient Requirements of Fish and Shrimp. 2011. The National Academies Press, Washington D. C. 376pp.

<sup>c</sup> Conversion factors for fat-soluble vitamins are as follows: 10,000 IU ≈ 3,000 µg vitamin A (retinol), 1 IU = 0.025 µg vitamin D (cholecalciferol).

<sup>d</sup> Diet without phospholipids

<sup>e</sup> As L-ascorbyl-2-monophosphate or L-ascorbyl-2-polyphosphate.

Table 9. Measurement Chart for making about 5 kg of Tilapia Feed in a 20 quart mixer bowl.

~5 kg batch		
Multipurpose Wheat Flour	grams	2100
Generic Tuna Fishmeal	grams	1400
Cooked Local Starch*	grams	1000
Plant Oil	mL	60
Vitamin Mix	grams	20
Trace Mineral Mix	grams	20
Water	mL	600
Total amount of feed (wet wt.)	kilograms	5.2

\*Cooked Local Starch is ulu or fa'i or taro, etc. Assume about 60% moisture.

Table 10. Measurement Chart for making different size batches of Tilapia Feed. Select the batch size that fits your mixer.

		Size of batch				
		1x	2x	5x	10x	15x
Multipurpose Wheat Flour	grams	525	1050	2625	5250	7875
Generic Tuna Fishmeal	grams	350	700	1750	3500	5250
Cooked Local Starch*	grams	150	300	750	1500	2250
Plant Oil	mL	15	30	75	150	225
Vitamin Mix	grams	5	10	25	50	75
Trace Mineral Mix	grams	5	10	25	50	75
Water	mL	150	300	750	1500	2250
Total amount of feed (wet wt.)	kilograms	1.2	2.4	6.0	12.0	18.0

\* Cooked Local Starch is ulu or fa'i or taro, etc. Assume about 60% moisture.

Table 11. Tilapia Mineral Mix\*\*\* Formulation by C. Lim (2007)\*.  
Manufactured by MPBiomedicals\*\*

Mineral	Units	Batch Size	
		1 kg	10 kg
Zinc Sulfate 7H <sub>2</sub> O	grams	87.920	879.20
Ferrous Sulfate 7H <sub>2</sub> O	grams	39.810	398.10
Manganese Sulfate H <sub>2</sub> O	grams	15.380	153.80
Copper Sulfate 5H <sub>2</sub> O	grams	2.356	23.56
Potassium Iodide	grams	1.300	13.00
Alphacel Non-Nutritive Bulk	grams	853.150	8531.50
Cobalt Chloride 6H <sub>2</sub> O	milligrams	40.0	400.0
Sodium Selenite	milligrams	39.0	390.0
Total batch weight		grams	999.995 9999.950

\*C. Lim. 2007. American Samoa Trip Report, December 8 – 16, 2007.

\*\*MP Biomedicals LLC, Solon, OH 44139

\*\*\*Application- Mineral Mix=4g/kg feed.

Table 12. Tilapia Vitamin Mix\*\*\* Formulation by C. Lim (2007)\*.  
Manufactured by MPBiomedicals\*\*

Vitamin	Units	Batch Size	
		1 kg	10 kg
Vitamin A Palmitate (250,000 IU/g)	grams	3.2	32
Vitamin D3 (400,000 IU/g)	grams	1.0	10
Menadione (for Vitamin K)	grams	2.0	20
Vitamin E (250 IU/g)	grams	80.0	800
Thiamine	grams	2.0	20
Riboflavin	grams	2.4	24
Pyridoxine	grams	2.0	20
D Calcium Pantothenate	grams	6.0	60
Niacin	grams	16.0	160
Folic Acid	grams	0.4	4
Vitamin B12 (0.1% Trit)	grams	2.0	20
Ascorbic Acid	grams	20.0	200
Alphacel Non-Nutritive Bulk	grams	862.96	8629.6
Biotin	milligrams	40.0	400
Total Batch Weight		grams	1000.0 10,000

\*C. Lim. 2007. American Samoa Trip Report, December 8 – 16, 2007.

\*\*MP Biomedicals LLC, Solon, OH 44139

\*\*\*Application- Vitamin Mix=4g/kg feed.

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**Appendices A - F**

**Feed Processing Techniques**  
**&**  
**Quality Control Tests**

## Making Tilapia Feed

### Prepare Ingredients

Grind/mash tuna meal, cooked starch.



### Mix Ingredients

Add all ingredients into mixer  
(flour, tuna meal, cooked starch,  
water, vitamins, minerals, & oil).

Mix 15 minutes.



### Make Strands

Put dough into the top of the meat grinder.

Collect the strands into a bucket.



### Dry Strands

Sun dry (about 1 day).



### Store & Feed

Break into smaller pieces.

Store in plastics bags in a cool dry place.

Feed your tilapia.

## **Making Tilapia Feed**

### **Preparing the ingredients:**

1. Grind the generic tuna fishmeal using the hammer mill.
2. Grind the cooked starch\* using the meat grinder, or mash it and set aside.
3. Measure out the amount of each ingredient needed & set aside.

Flour  
Generic Tuna Fishmeal  
Cooked Starch\*  
Water  
Vitamins  
Minerals  
Oil

\*cooked starch could be ulu, fa'i, taro, etc.

### **Mixing the ingredients:**

1. Use the Hobart mixer with the paddle attachment.
2. Add measured ingredients into the mixer bowl.
3. Mix for 15 minutes.\*\*

\*\*This mixing allows the wheat gluten in the flour to develop and hold the pellets together.

### **Making the dough into pellets:**

1. Use the meat grinder machine.
2. Scoop handfuls of the feed mash into the top of the meat grinder.
3. Gently collect the strands of fish food as they come out into a bucket\*\*\*

\*\*\*The strands may be too sticky to cut into pellets, so dry them first.

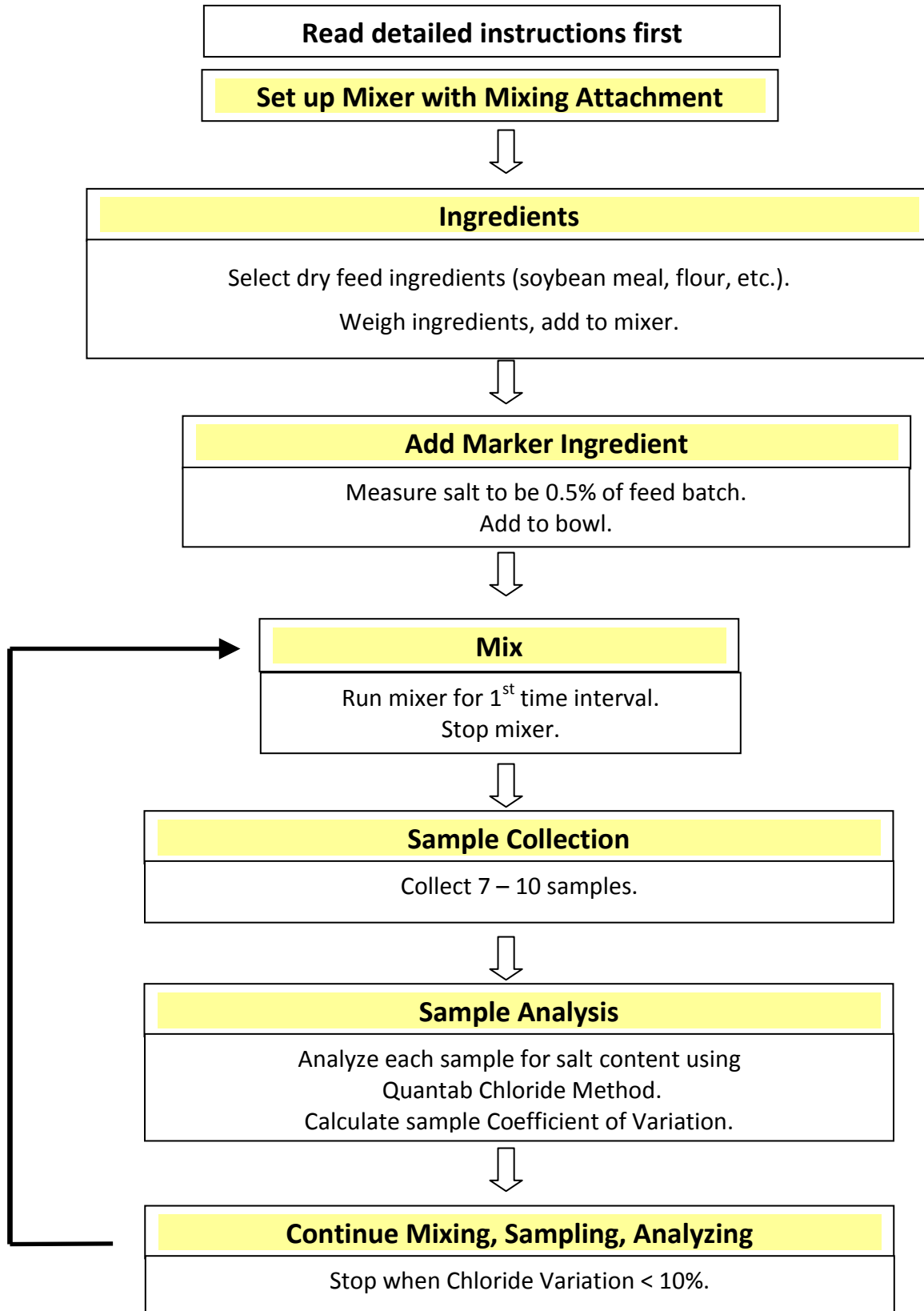
### **Drying the pellets:**

1. Spread the strands onto a tarp.
2. Let dry in the sun for about one day.

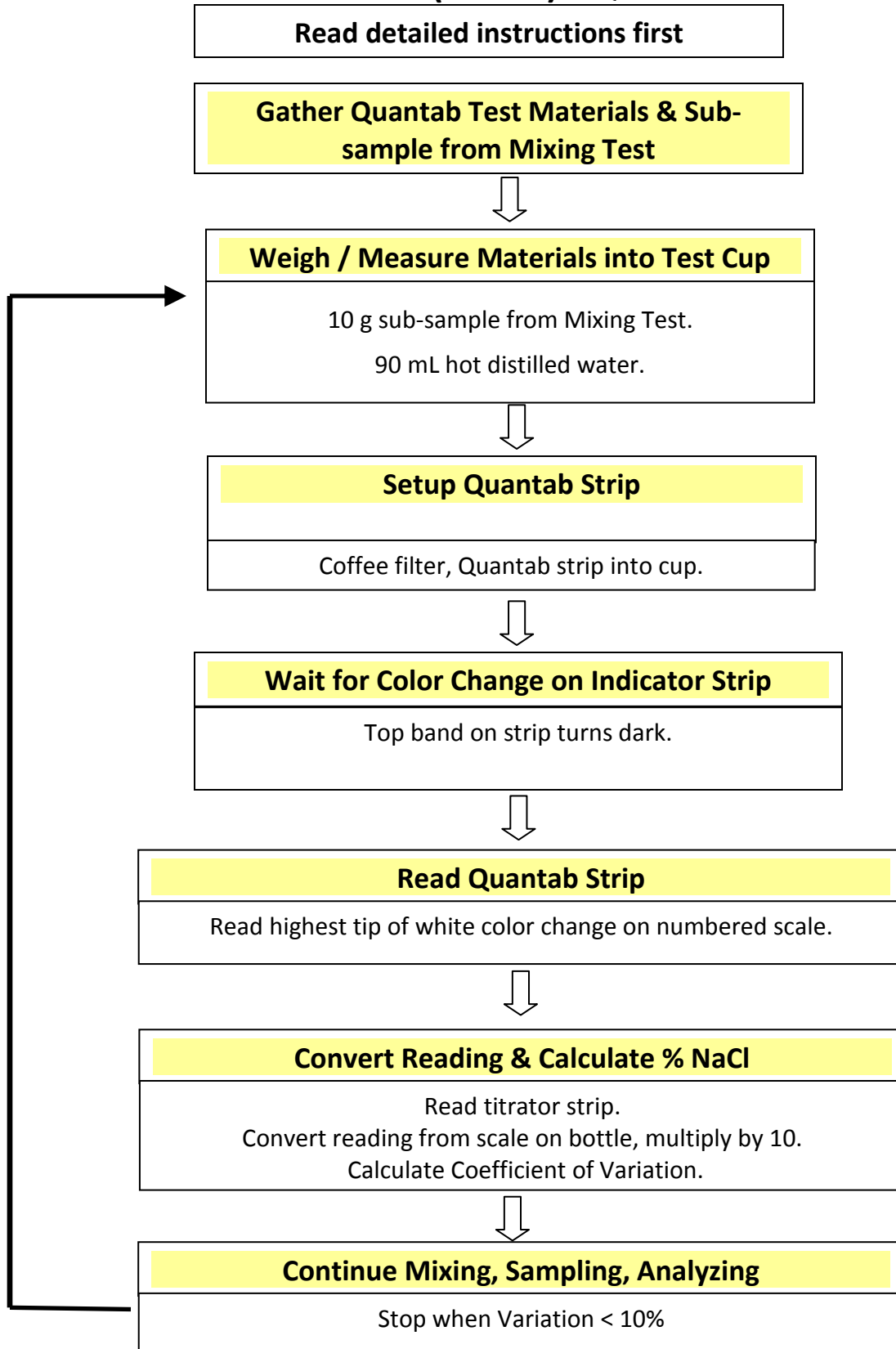
### **Storing and using the pellets:**

1. When dry, break the strands into smaller pieces.
2. Store the pellets in plastics bags in a cool dry place until you use them.
3. For feeding, break the pellet into smaller pieces to match the size of your fish's mouth.
4. Feed your tilapia. (If mold develops on feed do not feed. Use as fertilizer!)

## Mixer Performance Test<sup>1</sup>



## Mixer Performance (cont'd) - Quantab Method<sup>1</sup>



## Mixer Performance Testing<sup>1</sup>

### **Introduction:**

Mixing ingredients uniformly is very important. Consequences of a non-uniform mix are; a poor quality feed, poor animal growth and a waste of time, electricity and labor.

The mixer performance test will tell you how long you need to run your mixer for uniform mixing of ingredients with a minimum of mix time, electricity and labor. It will also let you know if your mixer is wearing out and mixing unevenly.

Factors for good mixing:

- Right amount of ingredients in the mixer: Fill the mixer so that the ingredients come at least ½ ways up the paddle to below the top of the paddle or for a ribbon mixer, according to manufacturer's specifications. Too little or too much ingredients create areas of poor mixing.
- Equipment cleanliness is very important: Carryover of old feed mix can contaminate subsequent mixes. It can also impede the efficiency of material movement within the mixer.
- Mixer Maintenance: Mixers will wear over time, so maintenance is important, as are periodic mixer tests. Replacing worn paddles is important because wear leads to dead spots, and eventually, inadequate mixes.
- Ingredient Particle Size: Ingredients should be ground to a small size and should be about the same size for all ingredients. Small particles mix better than large particles. Large particle size variation in a mix can result in segregation after mixing, so grind or mash your ingredients to a small size.

### **Mixer performance testing overview:**

The efficiency of the mixer is tested with a marker added to dry feed ingredients. After a mixing interval, samples are taken from several places around the mixer bowl or ribbon mixing chamber and analyzed to see how evenly the marker is distributed. A % coefficient of variation (%CV) is calculated. When the %CV is 10% or less, the test ends and the mixing time used is recorded.

Your test results will be valid only for the mixer on which you ran the test.

### ***Equipment needed***

- Hobart-type mixer with paddle attachment or horizontal ribbon mixer
- Scale for weighing, good to  $\pm 0.01$ g
- 3 to 4 kg dry test feed ingredients, such as soybean meal and/or flour, ground small
- Marker ingredient - Salt in fine, small particles at 0.5% of dry ingredient weight
- Grain probe (for taking samples)
- Numbered sample cups (to hold about 15 g of ingredients)
- Materials for Quantab chloride detection method (listed in later section)

Use dry feed ingredients that do not have salt in them, like flour and soybean meal. Use salt (NaCl) as the marker. Salt can be added in small amounts and can be easily detected using the Hach Quantab detection strips for chloride.

## Appendix B Mixer Performance Testing (cont'd)

### **Determining the mixing time intervals:**

1. Estimate the longest total time you might need to mix it (say 15 min.).
2. Divide into three time periods.
3. Mix, sample, & test the ingredients after each mixing time period.  
For example, 15 minutes total/ 3 time periods = five minutes per test period.

### **Mixing test procedures:**

1. Weigh test feed ingredient(s), approx 3 – 4 kg.
2. Put test ingredient(s) in mixer bowl so that it comes up at least ½ ways up the paddle to below the top of the paddle. Or for a ribbon mixer, fill according to manufacturer's specifications.
3. Weigh out salt to be 0.5% of the test ingredient(s) weight.  
For example, if weight of test ingredient(s) = 3 kg, salt weight = 15 g. For 4 kg ingredient(s) use 20 g of salt.
4. Add in the salt marker around the mixer bowl.
5. Mix for the 1<sup>st</sup> time interval of five minutes.
6. Stop the mixer.
7. Do not start again until after the sample analysis.
8. Take samples at seven to ten places around the mixing chamber, depending on your type of mixer. (See illustrations pg.23) Sample must be greater than 10 grams.
9. Analyze all the samples for salt using the Quantab method described below.
10. If the variation is greater than 10%, go back to Step 5, repeating the mixing for another five minutes, then take samples and analyze again.
  - Take samples in areas that might not be well mixed: along the edges of bowl and around the paddle. Take a vertical sample from top to bottom of the bowl.
  - Keep repeating the mixing, sampling and analysis at time intervals until the analysis shows a uniform mix of 10% or less variation. You may need to complete more than three mixing time periods.

### **Sample evaluation:**

Once samples are taken and properly labeled, they are analyzed for the presence of the marker. For salt using the Quantab method, the procedure below details how quickly results can be obtained. Once salt concentrations are obtained, the samples for the same mixing time can be compared statistically using the concept of Percent Coefficient of Variation (%CV).  $\%CV = (\text{Standard deviation} / \text{average}) \times 100\%$ . Acceptable variation within a mix occurs when the CV is 10% or below.

At the completion of the Mixer Performance Test, record how long the mixing time was needed for an even mix. Add up the time of your mixing periods to get the total time of mixing. In the future use this time for even mixing.

If you do this mixer test again later and it results in longer mixing times, it could mean that your mixer paddle is worn.

## Appendix B Mixer Performance Testing (cont'd)

### Quantab Method

#### **Materials:**

- Hach Quantab Titrators for Chloride strips\*, Low range 30 - 600 ppm of Cl<sup>-</sup> or 0.005% - 0.1% as NaCl
- Cups (to hold 10 g of sample and hot water)
- Unused coffee filters
- Hot distilled water

#### **Procedure:**

1. Label the sample cups with the sample #s.
2. Weigh 10 g of each sample into a separate cup.
3. Add 90 mL of hot distilled water to each cup.
4. Fold coffee filter in half twice and open into a cone shape. Pointed side down, place it into the cup deep enough to allow the solution to permeate into the filter cone.
5. Carefully place a Quantab titrator strip in the cone so that the bottom of the strip is immersed in the water. Be careful not to tear the filter. Feed particles can plug the titrator strip.
6. Leave the titrator in the solution until the yellow indicator strip across the top turn's dark.
7. Read the titrator strip on the numbered scale at the highest tip of the white color change.
8. Convert the reading to percentage of salt (%NaCl) from the calibration table on the bottle from which the titrator was taken. Use only the bottle from which the strip was taken. Different bottles (lots) of titrators can have different conversion tables on the bottles.
9. Multiply the %NaCl by 10 to account for the dilution (10 grams into 90 grams water, or 10%).
10. Calculate the % CV for each sampling time.
11. Repeat the mixing interval and sampling until you obtain a CV 10% or less.
12. Record the total time it took to get an even mix.

\*Quantab Titrator Strips can be ordered from the Hach catalogue, item#2744940 approximately \$42 for 40 test strips.

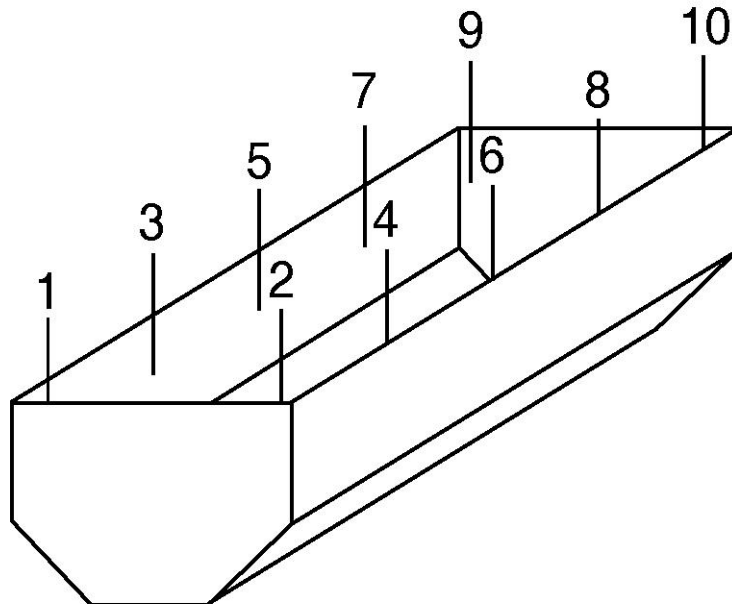
Hach Company: [www.hach.com](http://www.hach.com)

<sup>1</sup>McCoy, R.A. 2005. Mixer Testing, In: Feed Manufacturing Technology V (ed. by Schofield, E.K.), pp 620-622. American Feed Industry Association, Inc., Arlington, VA USA.

Appendix B Mixer Performance Testing (cont'd)



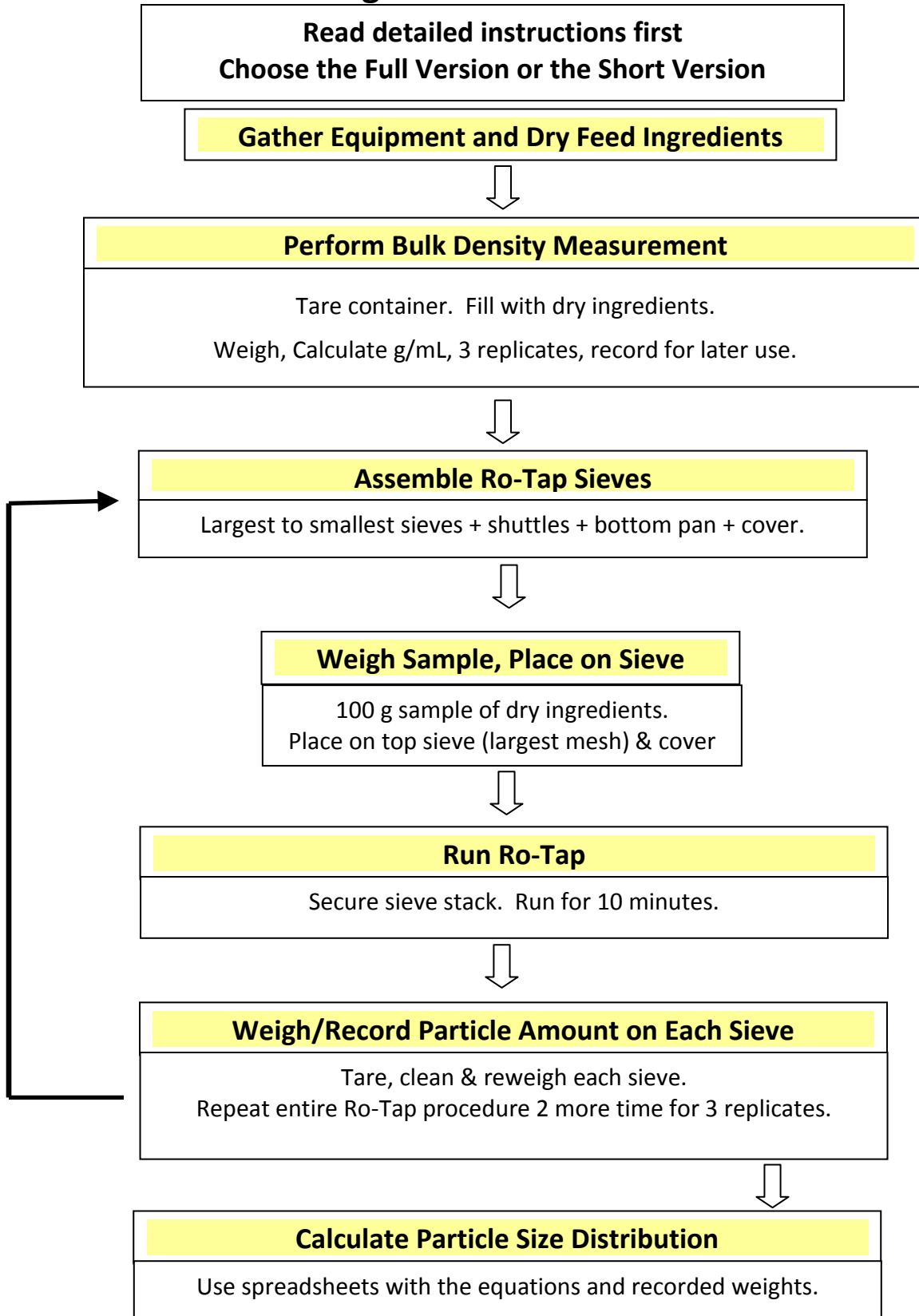
Sampling pattern for the Hobart Mixer (7 locations)



Sampling pattern for the Horizontal Ribbon Mixer (10 locations)

Illustration from Herrman, T. and K. Behnke, Testing Mixer Performance, Kansas State University, October 1994. <http://www.ksre.ksu.edu/library/grsci2/mf1172.aspx>

## Determining Particle Size Distribution<sup>3</sup>



## **Determining Particle Size Distribution, Method ASAE S319<sup>3</sup>**

**Overview:** Particle size can have an effect on how well or poorly the ingredients mix. It can tell you whether more grinding is needed. You can correlate the particle size with animal performance to see if finer particles might result in better digestion and growth. There are two versions of the Particle Size Distribution Test. One is the full version, which uses 15 sieves, and the other is the short version, which only uses 5 sieves. The procedure is the same for both versions of the test. The short version test takes less time and can be used when a quick check of particle size distribution is needed.

### **Materials & Equipment:**

- Ro-Tap model RX-29 Test Sieve Shaker (278 oscillations/min, 150 taps/min) (photo pg. 27)
- Clean, mesh sieves in a range of screen sizes listed in Table 1 or Table 2 (sieves are US standard test sieves, A.S.T.M. E-11, pictured pg. 27)
- One clean bottom pan
- One clean top cover
- Rubber nub shuttles, enough for one in each sieve (picture pg. 27)
- Brush shuttles, enough for one in each sieve (picture pg. 27)
- Top-loading balance (in grams)
- Container of known volume (for example plastic 250ml graduated cylinder cut off exactly at the 250 mark)
- Scraper – ruler or straight edge
- Dry materials to be tested
- Data sheet with the sieve sizes for recording weights
- Computer spreadsheets, long version and short version, preloaded with the needed distribution equations, graphs and examples, as referenced at the end of this document. Files are on accompanying CD.

### **Bulk density measurement – gram per surface area, used in later calculations:**

1. Tare the container of known volume.
2. Fill the container, gently scooping material into it until it overflows.
3. Using a ruler or straight edge, scrape once over the top to remove excess material.
4. Do not pack or compress the material.
5. Re-weigh the container and the material.
6. Record the weight in grams; this is the weight of the material.
7. Do this three times.
8. Calculate the average weight (g) per container of the material.
9. Divide the average weight by the volume of the container to get the weight per one mL (g/mL or g/cc).
10. Record this number (g/mL or g/cc).
11. Set this number aside for later use in the calculations.

## Appendix C. Determining Particle Size (cont'd).

### **Distributing the particles using the Ro-tap Sieve Shaker:**

1. Gather the sieves.
2. Make sure they are clean.
3. Clean & place one rubber nub shuttle and one brush shuttle onto each sieve.
4. Stack the sieves in descending size as they are listed in Table 1 or Table 2.
5. Make sure that the largest mesh sieve is on the top and the sieve sizes are in descending order with the smallest mesh sieve on the bottom.
6. Attach the bottom pan to the bottom of the stack of sieves.
7. Make sure that your test material is well mixed.
8. Take a 100 g subsample and place it on the top sieve.
9. Place the cover over the top sieve.
10. Secure the stack of sieves (with the subsample) in the Ro-Tap.
11. Turn the Ro-Tap on and allow to run (shake/oscillate) for 10 minutes.
12. Turn off the Ro-Tap.
13. Carefully remove the sieve stack from the Rotap shaker and place it near the balance.
14. Starting from the top, carefully remove a single sieve and tare it on the balance (the procedure to tare on a balance is explained below).
15. Vacuum and/or brush off the material from the sieve and two shuttles.
16. Return the sieve and two shuttles to the scale.
17. Read the negative weight. This is equivalent to the weight of sample that was on top of that sieve.
18. Record that sieve size and the weight as a positive number on your data sheet.
19. Repeat weighing, cleaning, re-weighing & recording weights, Steps 13 – 17, for all the sieves and bottom pan.
20. Repeat entire procedure, Steps 1–18, two more times for a total of three times.

### **Calculating the particle Size distribution:**

1. Use the long version or the short version spreadsheet pre-loaded with the equations, graphs & examples.
2. Use your samples weights per sieve recorded on your data sheet.
3. See following Appendix for the equations.

### **Notes:**

- The brush shuttle gently assists particles through the mesh openings of the sieve
- The rubber shuttle reduces static electricity interference that may build up from the brush.
- The material, the Ro-tap, and all other apparatus should be the same temperature. When a cold material is allowed to warm, it may gain weight in the ambient moisture which will skew results.
- Analytical sieve screens can be expensive and easily damaged. Follow the manufacturer's directions for cleaning, and in general be gentle to them.
- Inspect sieves regularly for damage and replace them if necessary

### **Procedure to tare an object on the balance & re-weighing the object:**

1. Set the object onto the balance.
2. Note that the balance will display a weight.
3. Press the balance bar or button, which will reset the balance to zero so that it does not display the weight of the object.
4. Empty, clean or fill the object and weigh it again. Do NOT reset the balance.

Appendix C. Determining Particle Size (cont'd).

5. If you have removed material from the object, the negative weight will reflect the weight of the material removed. Record this value as a positive number.
6. If you have filled the object, the positive weight will reflect the weight of the material added. Record this value.



U. S. Standard Test Sieve



Tyler Ro-Tap® Sieve Shake

Table 1. Full Version Sieve Stack

Tyler Screen #	U.S. Standard Screen #		
		Microns	Inch
4	4	> 4750	> 0.187
6	6	3360	0.1320
8	8	2380	0.0937
9	10	1680	0.0787
14	16	1190	0.0469
20	20	841	0.0331
28	30	594	0.0234
35	40	420	0.0165
48	50	297	0.0117
65	70	212	0.0083
100	100	150	0.0059
150	140	103	0.0041
200	200	73	0.0029
270	270	53	0.0021
400	400	37	0.0015
Pan	Pan	< 37	< 0.0015

Table 2. Short Version Sieve Stack

Tyler Screen #	U.S. Standard Screen #		
		Microns	Inch
14	16	1190	0.0469
28	30	594	0.0234
48	50	297	0.0117
100	100	150	0.0059
200	200	73	0.0029
Pan	Pan	< 73	< 0.0029

Appendix C. Determining Particle Size (cont'd).

Example - Full Version data sheet. The Short Version data sheet is similar, using only 5 sieves.

<b>Particle Size Distribution Data Sheet – Full Range Test</b>							
Sample ID: _____		Date of Analysis: _____					
Project: _____		Analyzed by: _____					
	Tyler Screen #	U.S. Standard Screen #	Mesh Size		Weights from each Replicate Run		
			Microns	Inch	Rep 1	Rep 2	Rep 3
					W <sub>1</sub>	W <sub>2</sub>	W <sub>3</sub>
				(g)	(g)	(g)	
1	4	4	> 4750	> 0.187			
2	6	6	3360	0.1320			
3	8	8	2380	0.0937			
4	9	10	1680	0.0787			
5	14	16	1190	0.0469			
6	20	20	841	0.0331			
7	28	30	594	0.0234			
8	35	40	420	0.0165			
9	48	50	297	0.0117			
10	65	70	212	0.0083			
11	100	100	150	0.0059			
12	150	140	103	0.0041			
13	200	200	73	0.0029			
14	270	270	53	0.0021			
15	400	400	37	0.0015			
	Pan	Pan	< 37	< 0.0015			
Bulk Density (g/200cc):							

Appendix C. Determining Particle Size (cont'd).

A CD with Excel spreadsheets containing the data sheets and all the calculations for the full range and short range tests and examples is included with this manual.

**Definitions for following Data Sheet & Equations:**

- $d_i$  = Diameter of sieve openings of the  $i$ 'th sieve
- $d_{i+1}$  = Diameter of sieve openings in the next larger than  $i$ 'th sieve
- $d_{gw}$  = Geometric mean particle size (diameter)
- $S_{gw}$  = Geometric standard deviation
- $W_i$  = Weight fraction on the  $i$ 'th sieve
- $\beta_s$  = Shape factor for calculating surface area of particles
- $\beta_v$  = Shape factor for calculating volume of particles
- $\rho$  = Specific weight of material
- $\sigma_{gw}$  = Geometric log-normal standard deviation of parent population by surface area distribution
- $\mu_{gw}$  = Geometric mean particle size or diameter of parent population by weight distribution

$$\log_{dw} = \frac{\sum W_i \log d_i}{\sum W_i} = 2.772$$

$$(\log S_{gw})^2 = \frac{\sum W_i (\log d_i - \log d_{gw})^2}{\sum W_i} = .1168$$

$$\log S_{gw} = .342$$

$$d_{gw} = 590$$

$$S_{gw} = 2.19$$

Example: Assume 1.4 gm/cc specific weight, 590 $\mu$  -  $d_{gw}$ , 2.19- $S_{gw}$ . then,

$$\begin{aligned} A_s &= \frac{6 \times 1}{1 \times 1.4} \exp[0.5(90.5 \ln 2.19)^2 - \ln 0.0590] \\ &= 4.28 \exp 0.5(0.784)^2 - (-2.82) \\ &= 4.28 \exp (3.13) \\ &= 98 \text{ cm}^2 \end{aligned}$$

Similarly, the number of particles per gram sample is calculated by the following:

$$N_1 = \frac{W_i}{\rho \beta_v} \exp(4.5 \ln^2 \sigma_{gw} - 3 \ln \mu_{gw})$$

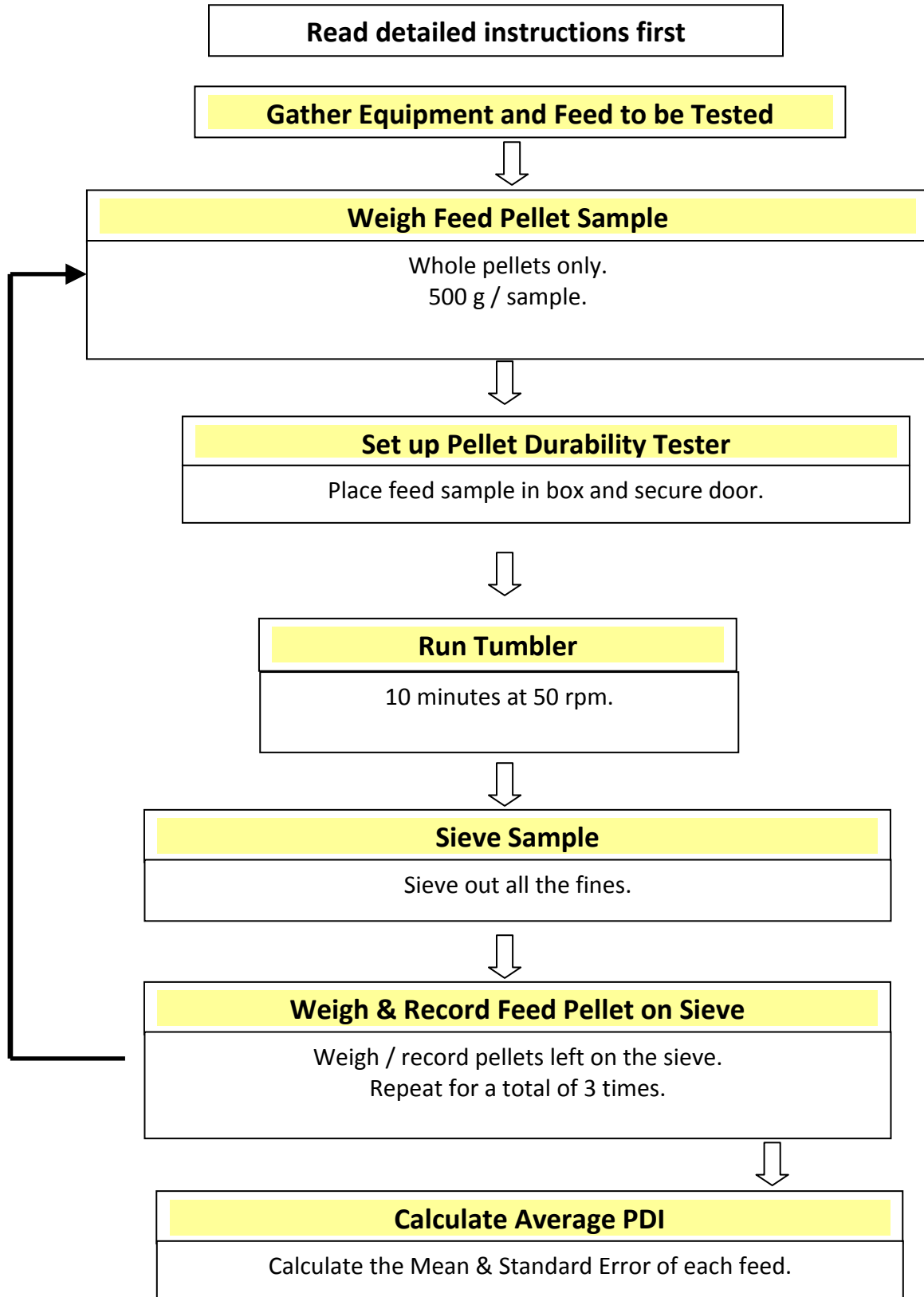
†

$$\begin{aligned} N_1 &= \frac{1}{1 \times 1.4} \exp[4.5 (\ln 2.19)^2 - 3 \ln 0.0590] \\ &= 0.714 \exp 4.5 (0.784)^2 - 3(-2.82) \\ &= 0.714 \exp(11.22) \\ &= 53,400 \text{ particles} \end{aligned}$$

<sup>3</sup>Benke, K. C. 2005. Determining and Expressing Particle Size, In: Feed Manufacturing Technology V (ed. by Schofield, E.K.), pp 617-619. American Feed Industry Association, Inc., Arlington, VA. Computer calculation spreadsheet for particle size determination provided by Kansas State University Department of Grain Science and Industry.

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## Pellet Durability Index (PDI)<sup>4</sup>



## **Pellet Durability Index (PDI)<sup>4</sup>**

**Overview:** Pellet Durability Index (PDI) measures the relative ability of the feed pellet to resist breaking up in the bulk handling system. Pellets are tumbled within a standardized dust-tight enclosure (picture pg. 34). The test consists of confining pellets in it and tumbling it for ten minutes at 50 rotations per minute. The sample is then screened using an analytical sieve with mesh openings as described in the chart on pg.34. The PDI is then calculated as the weight of pellets over the screen divided by the initial weight of pellets placed in the tumbler multiplied by 100 percent. In this way, the PDI is the percentage of material that resists shattering such that it is large enough to be considered a pellet.

### **Equipment and Test Apparatus:**

- Pellet Durability Tester (Continental-Agra Grain Equip., INC. Newton, KS 67114)
- Appropriate wire sieve (see pg. 34).
- Balance with accuracy of  $\pm 0.01$ .
- 1.5 kg of Feed pellets to be tested.
- Five ½ - inch hex-nuts, for aquaculture feeds only (see Note below).

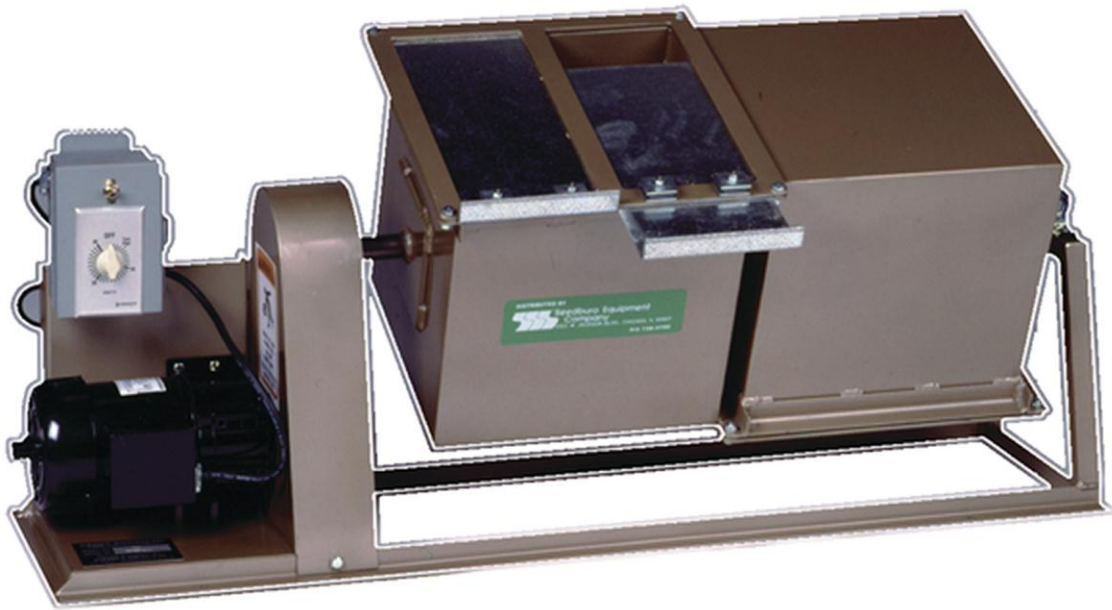
### **Procedure:**

1. Take a representative sub-sample of the pellets and remove any broken pieces.
2. Weigh 500.00 grams of the feed pellets
3. Place the sample into the tumbling apparatus and secure it
4. Tumble for 10 min at 50 rpm
5. Remove all of the sample and place it into the appropriate sieve
6. Sieve out the fines and weigh the amount of material that is over the sieve
7. Record the weight.
8. Repeat steps 1 - 6 for a total of 3 replicate tumblings.
9. Calculate the Mean and Standard Error of each feed.

### **Notes:**

- Aquatic feed pellets are much harder and have a higher PDI than most conventionally processed animal feed pellets. The pellet hardness and high PDIs are due to fine ingredient particle sizes and severe processing methods. The hardness of aquatic feed pellets in a standard PDI test (without hex nuts) often yields PDI results of poor resolution. Because of this difficulty in differentiating PDI's between aquatic feeds, a more severe PDI test was devised by adding five ½-inch hex-nuts to each tumbling compartment.
- An important consideration is the determination of the correct sieve size. The following chart is helpful in this respect and in situations outside of the range of the chart extrapolation. Common sense must be applied in choosing the best sieve, as it will determine whether a sample is a "pellet" that has survived the tumbling test, or a "fines" portion that has succumbed to tumbling actions. Appropriate sieves should be chosen such that the sieve size is the first sieve size with a nominal opening smaller than the pellet diameter.
- The pellets, tumbling box, and sieve should be about the same temperature to avoid loss or gain in weight as a result of ambient moisture in the air.
- Whole pellets should be selected for testing.

- Appendix D. Pellet Durability Index (cont'd)



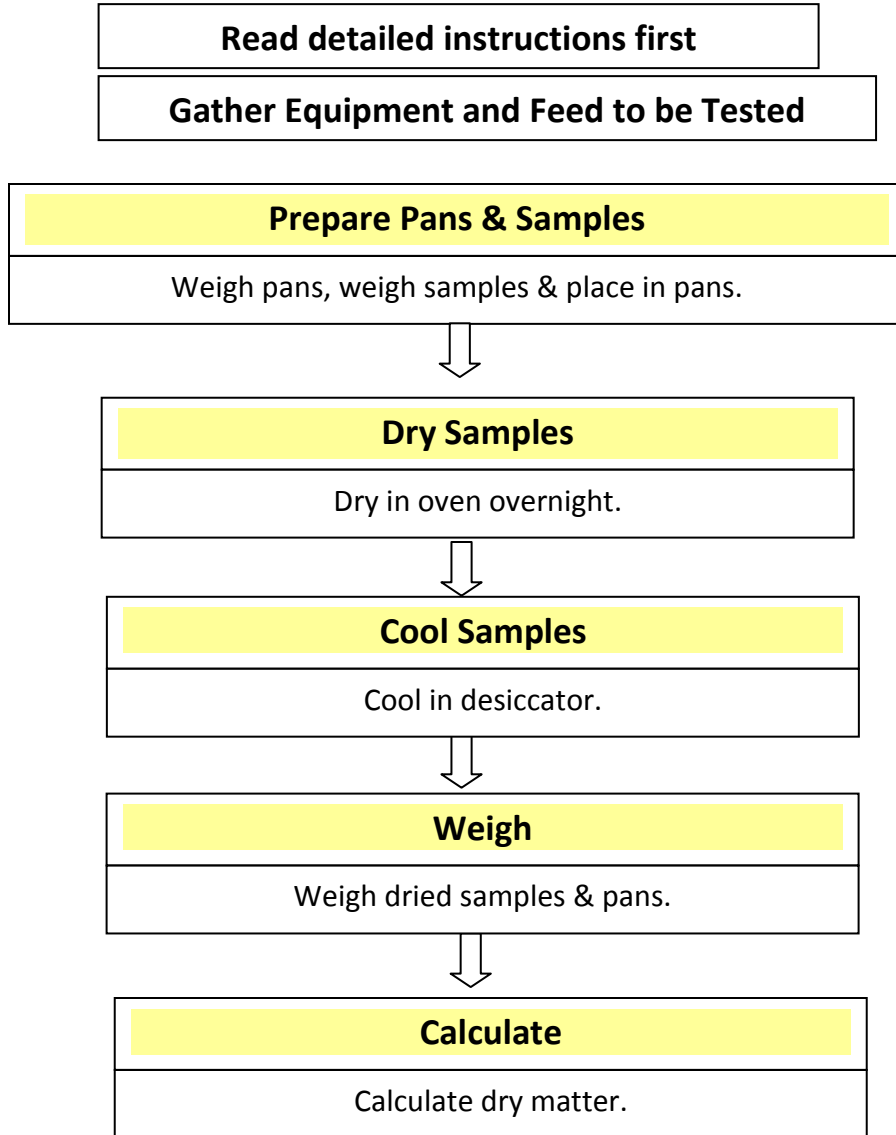
**Pellet Durability Tester**

pellet size			required screen size for PDI analysis		
(inches)	(inches)	(mm)	ASTM Size (No.)	(inches)	mm
3/32	0.0938	2.4	10	0.0787	2.0
1/8	0.1250	3.2	7	0.1110	2.8
9/64	0.1406	3.6	6	0.1320	3.4
5/32	0.1563	4.0	6	0.1320	3.4
3/16	0.1875	4.8	5	0.1570	4.0
13/64	0.2031	5.2	4	0.1870	4.7
1/4	0.2500	6.4	3.5	0.2230	5.7
5/16	0.3125	7.9	0.263	0.2650	6.7
3/8	0.3750	9.5	5/16	0.3125	7.9
1/2	0.5000	12.7	7/16	0.4375	11.1
5/8	0.6250	15.9	0.53	0.5300	13.5
3/4	0.7500	19.1	5/8	0.6250	15.9
7/8	0.8750	22.2	3/4	0.7500	19.1
1	1.0000	25.4	7/8	0.8750	22.2

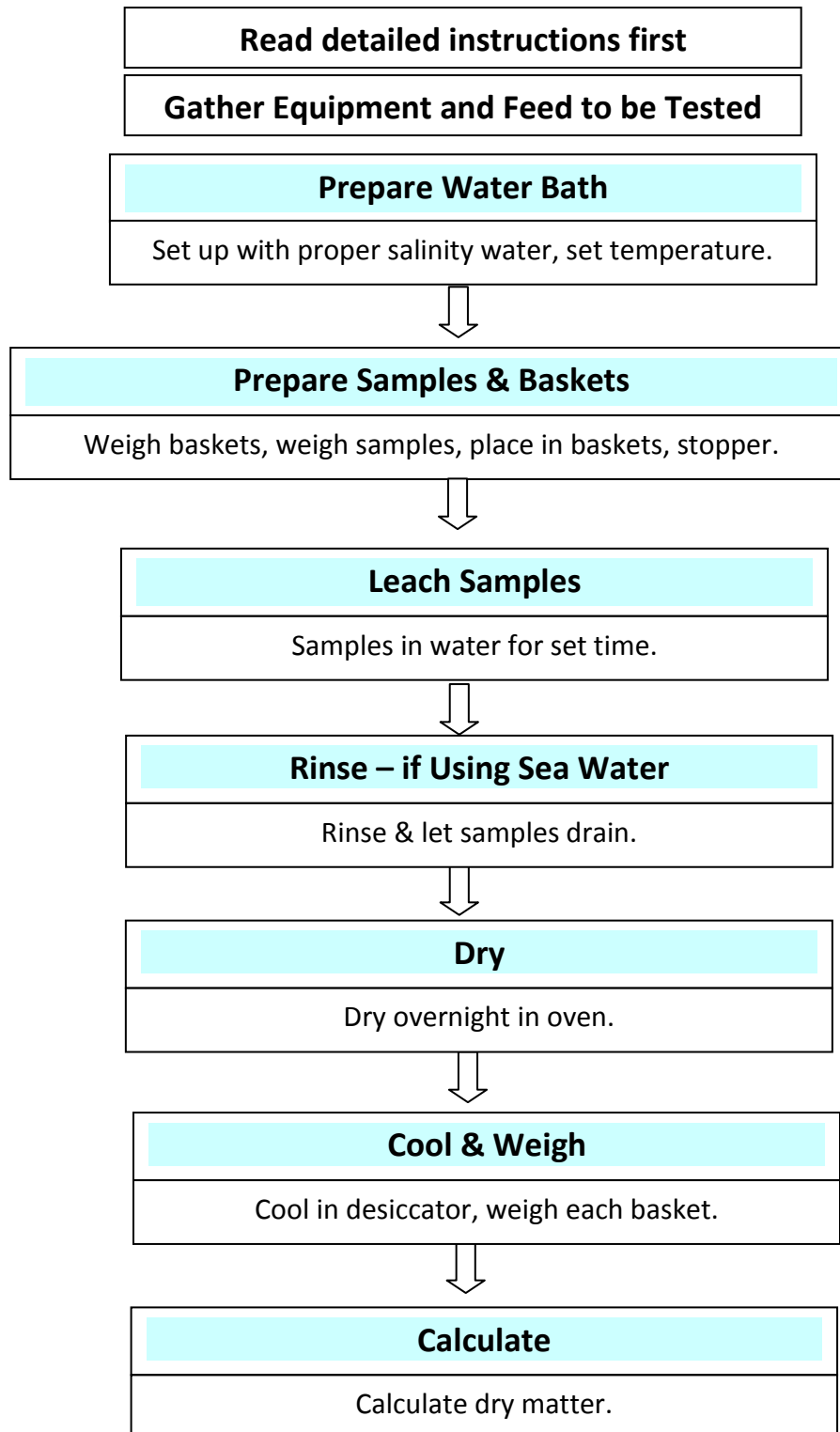
<sup>4</sup>American Society of Agricultural Engineers. ASAE 5269.3, Wafers, Pellets and Crumbles – Definitions and Methods for Determining Specific Weight, Durability and Moisture Content, In: Feed Manufacturing Technology V, 2005 (ed. by Schofield, E.K.), pp 617-619. American Feed Industry Association, Inc., Arlington, VA.

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## Non-Leaching Procedure Pellet Water Stability Protocol<sup>5</sup>



## Leaching Procedure Pellet Water Stability Protocol<sup>5</sup>



## **Pellet Water Stability Protocol<sup>5</sup>**

**Overview:** Stability of the feed pellet in tank or pond water can have an effect on how much nutrition the aquatic animal receives. Pellet water stability is determined by the loss of dry matter through a #40 mesh screen while immersed in a temperature controlled volume of water for a predetermined amount of time. It is a relative measure of dry matter retention under controlled conditions. Both leaching and physical degradation contribute to dry matter loss and inversely, dry matter retention.

### **Typical ranges of testing include:**

- 2-45 samples sharing 4L water
- $25 \pm 0.5^{\circ}\text{C}$
- Static Leaching condition (non-circulating waterbath)
- Leaching times of 1,2, and/or 4 hours
- Leaching baskets made of 40 mesh screen

### **Full ranges of testing include:**

- Static, vertical, or horizontal agitation conditions
- Full saltwater to freshwater leaching at volumes of 4-10 liters
- Variable leaching times
- $5^{\circ}\text{C}$  above ambient to  $100^{\circ}\text{C}$  waterbath range

### **Equipment and Test Apparatus:**

- Lindberg Blue waterbath model: RSWB3222A-1
- Lindberg Blue chiller model: RSWB3222A-2
- VanKel stainless steel 40 mesh dissolution basket (part no. 12-2100)
- Size 3 rubber stoppers
- Rack for baskets
- Thelco drying oven set at  $105^{\circ}\text{C}$
- Desiccator box for cooling, with rechargeable desiccant
- Aluminum pans
- 11 liter container for leaching
- Timer for tracking and assuring desired leaching times
- Feed pellets to be tested

### **Notes on replication:**

- All samples are replicated in triplicate.
- For dry matter, it suffices to weigh separate samples into separate pans three times per sample, drying and cooling in a single batch.
- For leaching, replicates cannot be allowed to leach in the same volume of water. Leach one replicate of each sample separately.

**Pellet Water Stability Test Procedure:**

Dry matter retention is determined on pellet samples both *leached* and *unleached* under test conditions. The latter is a simple determination of moisture content of the pellet sample and is required to offset differences in sample moisture prior to leaching.

- **Non-leaching dry matter procedure (via oven drying)**
  1. Obtain three clean labeled aluminum pans per feed sample; each sample is run in triplicate.
  2. Separately weigh and record the weight of the each aluminum pan.
  3. Add approximately 2 grams of the feed pellets onto the pan, reweigh, and record initial samples weight.
  4. Repeat until each feed sample has been weighed into pre-weighed aluminum pans in triplicate.
  5. Place all samples in aluminum pan in the drying oven set at 105°C, and leave overnight.
  6. Make sure desiccants are charged and in desiccator for the next morning.
  7. Hot dry matter feed pellet samples and their aluminum pans are removed and immediately placed in the desiccator to cool to ambient temperatures (c.a. 15 min.).
  8. Upon removal from the desiccator, the aluminum pan and the dried feed sample are immediately weighed and recorded.
  9. The weight of the pan is subtracted from the sample+pan weight for both the initial and also the dried feed weight.
  
- **Leaching procedure of pellet stability samples** (photo next page)
  1. Weigh and record the basket number and weight of a clean and dry 40 mesh dissolution basket.
  2. Add 2.00 g ( $\pm 0.01$ g) of feed sample to the basket, reweigh, and record weight.
  3. Place a #3 stopper in the basket and prepare it for optimum arrangement of samples in appropriate metal rack.
  4. Have sufficient quantity of water of the appropriate salinity prepared and put into the water bath (could be fresh water or sea water).
  5. Setup and warm-up the waterbath to maintain desired temperature.
  6. Gently submerge entire rack of 40 mesh baskets containing samples and start the timer.
  7. Gently remove rack when the timer alerts, and place on counter to allow water the opportunity to drain (40 mesh sometimes drains slowly due to water tension).
  8. If sea water was used, prepare freshwater rinsing bath with the same volume of water used in leaching, but this time in freshwater to rinse salt.
  9. If rinsing is needed, allow the baskets and samples to sit in the water for 1 minute.
  10. Gently remove basket rack, carefully remove all rubber stoppers and place the whole rack in the oven for drying overnight at 105°C.

Appendix E. Pellet Water Stability (cont'd).

11. The next morning remove the samples and place whole rack into a desiccator box for cooling.
12. When cool, weigh and record the weight of each basket.
13. Depending on the sample arrangement, this procedure is repeated such that each sample is run in triplicate, under separate instances of leaching, but under identical circumstances.

**Calculations:**

1. Dry matter determinations
  - a. % Dry matter is calculated as:  $(\text{final wt}) / (\text{initial wt}) * 100\%$
  - b. Calculate dry matter of leached AND unleached sample
2. % Pellet Stability is calculated as:  $(\% \text{dry matter of leached sample}) / (\% \text{dry matter of unleached sample}) * 100\%$
3. Upon calculating the % pellet stability for each sample in triplicate, the data is then prepared for statistical analysis, and reported to Principal Investigator.



Baskets (without stoppers) & Rack set in water bath

<sup>5</sup>Oceanic Institute Standard Protocol for Pellet Water Stability.

## Appendix F. Equipment Procurement Resource Guide

Protocol	Manufacturer*	Description	Model#	Cost (USD\$)	Freight (USD\$)
<b>Moisture Testing</b>					
	Sartorius Mechatronics Corp.	Moisture Analyzer	Mark 3-LTE w/ Printer	4585.00	1410.00
<b>Mixer Performance Testing</b>					
	Hach	QuanTab Titrator Strip for Chloride	2744940	41.79	44.95
<b>Particle Size Distribution</b>					
	W.S. Tyler Indus. Group	Ro-Tap Sieve Shaker	RX-29	2074.00	
	W.S. Tyler Indus. Group	no. 4, 4.75 mm Sieve	5355	64.10	
	W.S. Tyler Indus. Group	no. 6, 3.35 mm Sieve	5357	64.10	
	W.S. Tyler Indus. Group	no. 8, 2.36 mm Sieve	5359	64.10	
	W.S. Tyler Indus. Group	no. 12, 1.7 mm Sieve	5361	64.10	
	W.S. Tyler Indus. Group	no. 16, 1.18 mm Sieve	5363	64.10	
	W.S. Tyler Indus. Group	no. 20, 850 μ Sieve	5365	64.10	
	W.S. Tyler Indus. Group	no. 30, 600 μ Sieve	5367	64.10	
	W.S. Tyler Indus. Group	no. 40, 425 μ Sieve	5369	64.10	980.00
	W.S. Tyler Indus. Group	no. 50, 300 μ Sieve	5371	64.10	
	W.S. Tyler Indus. Group	no. 70, 212 μ Sieve	5373	64.10	
	W.S. Tyler Indus. Group	no. 100, 150 μ Sieve	5375	65.90	
	W.S. Tyler Indus. Group	no. 140, 106 μ Sieve	5377	73.70	
	W.S. Tyler Indus. Group	no. 200, 75 μ Sieve	5379	86.90	
	W.S. Tyler Indus. Group	no. 270, 53 μ Sieve	5381	114.20	
	W.S. Tyler Indus. Group	no. 400, 38 μ Sieve	5383	164.40	
	W.S. Tyler Indus. Group	Pan	8492	45.10	
	Codema LLC	Molded Stud Sieve Shuttle	SIF-SIE-00201	78.00	25.00
	Codema LLC	Black Bristle Sieve Shuttle	SIF-SIE-00100	72.00	25.00
<b>Pellet Durability Index</b>					
	Seedboro Equipment Co.	4 Compartment Pellet Durability Tester	PDT	2435.00	635.00
<b>Pellet Water Stability</b>					
	Fisher Scientific	28L IsoTemp Digital Water Bath	Fisher IsoTemp 15-462 series model 228	1239.78	461.62
	Yanjiang Factory China	Stainless steel Mesh Ball Tea Infuser (12)	See Description	240.00	250.00

\*Manufacturer full contact information on following page.

μ = micron

## Appendix F. Equipment Procurement Guide (cont'd)

### Manufacturer Contact Information

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