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Range in starch content and digestibility of common starch sources in US and Japan and their effect on in vitro microbial biomass production when incorporated into total mixed rations



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INTRODUCTION

- Advanced nutrition and higher feed costs have resulted in the need for analyzed starch and starch digestibility values in ration formulation
- Common methods used for starch and starch digestibility include:
 - Enzymatic
 - Batch culture
 - Gas fermentation
- There is increased need and value in understanding associative effects of starch grains with various forages in TMR
- Current feed libraries provide "average" nutrient values for feed type
- There are few data sets evaluating starch digestibility across analytical methods

OBJECTIVE

- Evaluate the range of starch, starch digestibility, and associative effects of starch on TMR fermentation characteristics of the most commonly fed starch-based grains

MATERIALS AND METHODS

Samples

- Obtained samples of the primary starch grains from US, Canada and Japan (Table 1)
- Starch sources
 - Corn meal fine/medium
 - Corn cracked
 - Corn flaked
 - Corn rolled
 - Corn grain Argentina (Arg)
 - Barley ground
 - Rice ground
 - Rice whole
 - Wheat flaked
 - Wheat ground
 - Wheat whole
 - Sorghum ground

Analysis

- Starch and starch digestibility measured enzymatically at 2 h and 7 h (starch-d 2 h, starch-d 7 h): Cumberland Valley Analytical Services (CVAS, Hagerstown MD)
- Fermentrics™ (Dairyland, Labs Arcadia WI)
 - Gas production analysis:
 - In vitro fermentation system
 - Designed to measure associative effects
- Based on CVAS results a high starch-d sample was selected from each grain type for Fermentrics™ analysis of individual grain and when mixed in 3 different TMRs
 - A high and low starch-d sample was selected from corn meals (corn meal 1 - high starch-d, corn meal 2 - low starch-d)
- TMRs of different forages with selected grains
 - Corn silage (CS) and hay crop silage (HCS) based
 - Hay based: alfalfa, timothy and oat hay
 - HCS based: native grass and reed canary

Fermentrics™: Brief interpretation of output and reference values

(Jay Johnston, www.fermentrics.com)

- Apparent partitioning factor (aPartitioning Factor)
 - Efficiency of fermentation
 - (SCVFA + Microbial protein) / total gas
 - Reference value goal >4
- Apparent organic matter digestion (aOMD%)
 - <50% milk production poor
 - ~60% milk production reasonable
 - >65% milk production good, but rumen health may be at risk, monitor CHO pool size and kd
- Microbial biomass production: MBP(mg/g)
 - "Gold standard parameter" highly related to milk production
 - MBP x 0.41 x 1.3 x DMI kg = microbial protein (g/d)
 - >140 mg/g associated with better cow response

RESULTS

Table 1. Starch content and digestibility of samples received

Feed/Grain	n	Starch	Range	Starch-d 2 h	Range	Starch-d 7 h	Range
Corn meal (fine/medium)	17	73.2	71.4 – 75.8	10.9	5.2 – 14.7	51.3	44.9 – 56.4
Corn cracked	9	73.3	70.7 – 76.3	8.0	4.6 – 11.3	41.7	32.4 – 56.8
Corn flaked	11	74.5	72.2 – 77.3	11.9	7.7 – 20.6	52.7	40.3 – 63.0
Corn rolled	3	74.5	72.8 – 75.3	11.8	5.2 – 16.9	51.1	45.7 – 60.7
Corn grain Arg	1	69.9	--	11.4	--	51.4	--
Barley ground	4	59.7	55.3 – 63.9	12.4	3.9 – 18.8	57.4	46.2 – 62.4
Rice ground	1	75.4	--	4.3	--	21.7	--
Rice whole	8	79.7	77.3 – 82.2	5.4	4.0 – 8.4	16.8	13.5 – 18.0
Wheat flaked	2	67.8	65.8 – 69.8	16.5	10.8 – 22.4	57.5	53.9 – 61.1
Wheat ground	4	67.7	66.4 – 69.8	15.1	13.0 – 17.2	59.7	55.4 – 62.5
Wheat whole	5	68.3	63.8 – 72.7	22.0	20.4 – 23.3	47.2	43.4 – 51.5
Sorghum ground	1	63.8	--	0.8	--	32.6	--

Table 2. Grains selected for individual and TMR gas fermentation ranked by starch, starch-d 7 h, digestible starch and MBP

Rank	Starch	%	Starch-d 7 h	%	Digestible starch 7 h	%	MBP mg/g
1	Rice	75.4	Corn flaked	63.0	Corn flaked	47.4	Rice 332.5
2	Corn flaked	75.3	Wheat	62.2	Rice	43.7	Corn flaked 266.0
3	Corn meal 1	73.4	Barley	61.5	Wheat	43.4	Corn Arg 248.0
4	Corn meal 2	72.8	Rice	58.0	Corn meal 1	41.4	Barley 248.0
5	Corn Arg	69.9	Corn meal 1	56.4	Corn Arg	35.9	Wheat 238.0
6	Wheat	69.8	Corn Arg	51.4	Barley	34.0	Corn meal 1 186.5
7	Barley	55.3	Corn meal 2	46.6	Corn meal 2	33.9	Corn meal 2 174.0

Note change in ranking of grains across various methods. Rice and corn flaked tend to be highly ranked across methods of starch evaluation.

Table 3. Corn silage and hay crop silage based TMR

	Corn meal 1 % of DM	Corn meal 2 % of DM	Corn flaked % of DM	Barley % of DM	Rice % of DM	Wheat % of DM	Corn Arg % of DM
Forages							
CS	24.6	24.6	24.6	24.6	24.6	24.6	24.6
HCS	30.3	30.3	30.3	30.3	30.3	30.3	30.3
% Forage	54.9	54.9	54.9	54.9	54.9	54.9	54.8
Concentrates							
SBM	5.0	5.0	5.0	3.8	6.4	3.1	5.0
Soy Pass	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Grain	11.4	11.4	11.4	11.4	11.4	11.4	11.3
Beet Pulp PL	5.7	5.7	5.7	0.0	4.5	6.4	5.2
Starch Grains							
Corn meal 1	19.3	-	-	-	-	-	-
Corn meal 2	-	19.3	-	-	-	-	-
Corn flake	-	-	19.3	-	-	-	-
Barley	-	-	-	26.2	-	-	-
Rice	-	-	-	-	19.1	-	-
Wheat	-	-	-	-	-	20.5	-
Corn Arg	-	-	-	-	-	-	19.9
Nutrient Profile of TMR as predicted with CPM 3.0							
CP	16.7	16.7	16.7	16.7	16.8	16.7	16.7
NDF	36.4	36.4	36.4	37.9	36.4	36.8	36.2
Starch	24.6	24.5	25.0	24.7	24.9	24.7	24.4

Table 4. Hay based TMR

	Corn meal 1 % of DM	Corn meal 2 % of DM	Corn flaked % of DM	Barley % of DM	Rice % of DM	Wheat % of DM	Corn Arg % of DM
Forages							
Hay Alfalfa	19.0	19.0	19.0	18.9	19.0	18.9	19.0
Hay Timothy	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Hay Oat	7.6	7.6	7.6	5.3	7.6	7.6	7.6
% Forage	42.6	42.6	42.6	40.2	42.6	42.4	42.6
Concentrates							
SBM	3.8	3.8	3.8	1.5	6.4	0.7	3.8
Soy Pass	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Grain	11.4	11.4	11.4	11.3	11.4	11.3	11.4
Beet Pulp PL	6.9	6.9	6.9	0.7	5.0	8.4	5.9
Starch Grains							
Corn meal 1	31.6	-	-	-	-	-	-
Corn meal 2	-	31.6	-	-	-	-	-
Corn flake	-	-	31.6	-	-	-	-
Barley	-	-	-	42.4	-	-	-
Rice	-	-	-	-	30.9	-	-
Wheat	-	-	-	-	-	33.3	-
Corn Arg	-	-	-	-	-	-	32.6
Nutrient Profile of TMR as predicted with CPM 3.0							
CP	16.7	16.7	16.7	16.9	16.8	16.4	16.7
NDF	33.1	33.1	33.1	35.2	33.1	33.8	32.8
Starch	24.9	24.7	25.5	24.9	25.0	25.0	24.5

Table 5. Hay crop silage based TMR

	Corn meal 1 % of DM	Corn meal 2 % of DM	Corn flaked % of DM	Barley % of DM	Rice % of DM	Wheat % of DM	Corn Arg % of DM
Forages							
HCS	49.7	49.7	49.7	40.5	49.7	49.8	49.6
% Forage	49.7	49.7	49.7	40.5	49.7	49.8	49.6
Concentrates							
SBM	1.2	1.2	1.2	-	3.5	-	1.2
Soy Pass	3.8	3.8	3.8	3.1	3.8	1.6	3.8
Grain	11.4	11.4	11.4	11.4	11.4	11.5	11.4
Beet Pulp PL	1.9	1.9	1.9	2.2	0.5	3.5	1.0
Starch Grains							
Corn meal 1	32.0	-	-	-	-	-	-
Corn meal 2	-	32.0	-	-	-	-	-
Corn flake	-	-	32.0	-	-	-	-
Barley	-	-	-	42.7	-	-	-
Rice	-	-	-	-	31.1	-	-
Wheat	-	-	-	-	-	33.7	-
Corn Arg	-	-	-	-	-	-	33.0
Nutrient Profile of TMR as predicted with CPM 3.0							
CP	16.6	16.6	16.6	16.7	16.6	16.2	16.6
NDF	37.3	37.3	37.3	38.3	37.5	37.8	37.0
Starch	24.7	24.5	25.3	24.7	24.7	24.7	24.2

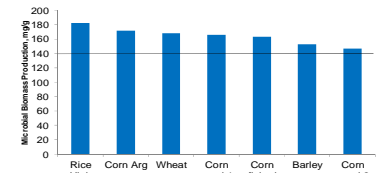


Figure 1. Fermentrics™ MBP results of corn silage TMR

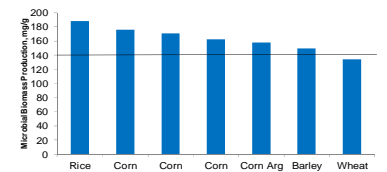


Figure 2. Fermentrics™ MBP results of hay TMR

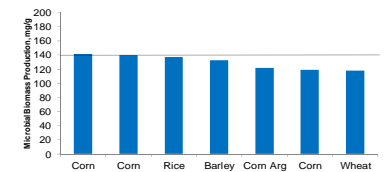


Figure 3. Fermentrics™ MBP results of hay crop silage TMR

Table 6. Fermentrics™ summary of the high starch digestibility samples of the four major grain types as ground grain

Feed Grain Substitution Basis	Corn meal 1 Starch / 1:1	Barley Starch	Rice Starch	Wheat Starch
aPartitioning Factor				
CS TMR	4.8	3.5	4.0	5.2
Hay TMR	4.4	3.5	4.5	3.4
HCS TMR	5.4	6.4	6.7	4.0
aOMD,%				
CS TMR	58.5	51.8	57.0	59.2
Hay TMR	53.4	53.4	60.0	53.0
HCS TMR	57.2	57.6	56.7	53.2
Microbial Biomass Production, mg/g				
CS TMR	166.0	152.5	182.5	168.0
Hay TMR	171.0	149.5	188.0	134.0
HCS TMR	141.5	132.5	137.0	118.0

Conclusions

- Current lab analyses do not always rank starch grains similarly comparing enzymatic starch-d 7 h with gas fermentation MBP results
- Fermentrics™ gas fermentation indicate that starch grains influence fermentation differently depending on the forage base