Studies on the Rates of Evaporation and *In Vitro* Digestibilities of Different Proportions of Starch Pulp and Seaweed Meal

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海藻紛과 澱粕粉의 配合比率이 水分蒸發과 *In Vitro* 消化率에 미치는 影響

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Summary

Two experiments were conducted to improve quality of some feedstuff resources for farm animals using seaweeds and sweet potato starch pulp produced in Jeju Island. Sweet potato starch pulp was replaced by seaweed meal at 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, and 0% levels for each treatments.

To enhance the rate of moisture evaporation of the different proportions of seaweed meal and starch pulp mixtures, the experiment 1 was conducted. In the experiment 2, *in vitro* fermentation was run using rumen fluid collected from a Korean goat to find out proper proportion of mixture between seaweed meal and starch pulp. In the experiment 1, the highest evaporation rate was 10% seaweed meal treatment lot followed by in order of 20% seaweed meal treatment lot and 30% seaweed meal treatment lot. In the experiment 2, the highest *in vitro* digestibility was the 40% seaweed meal mixture lot for digestibility of dry matter (DDM) and organic matter digestibility (OMD). For digestibility of organic matter (DOM) 30% seaweed meal was found the highest. There were statistically significant interactions ($P < 0.05$) among the *in vitro* DOM in all treatment lots.

Introduction

In view of profitable livestock management the immediate problems faced by Korean animal raisers are to minimise the feed costs through increasing production of feedstuffs and exploiting possible resources in Korea, a peninsula, with narrow cultivative land with over populated.

Seaweed and starch pulp is possible items to be exploited as feed stuff resources. Seaweeds are consisted of edible and inedible which is mainly used for mannure. In 1978, the total production of dry seaweeds was 77,634 M/T from that 35,000 M/T was inedible seaweeds. In Jeju, the total figure of seaweed production in 1978 was 35,125 MT/ with 25,000 M/T of inedible seaweeds. Brown alage distributed at east and south coast of Korea could be harvested up to 600,000 M/T. Seaweeds growing at Soguipo coast are 101 species consisting 18 species of green algae, 36 species of brown algae, and 41 species of red algae. Major seaweed associations are Ishige, Porphyra Gloiopeltis, Hizika Fusiforme, Sargassum and Corallina Association.

Total production of sweet potatoes in 1978 was 552,837 M/T from that 134,857 M/T were processed for starch producing approximately 1,400 M/T of starch pulp. The entire amounts of that figures are not fully utilized for animal feeding. Wet starch pulp produced from small units of starch manufacturing factories piled hundreds of tons for months. Dewatering processing is not available at each units. Thus starch pulp produce bad smell until transported to individual farms as wet form that cost much. Seaweeds contain high macro and micro minerals. They vary to species, cutting and harvesting seasons ranging from 9% to 45% in dry matter basis and up to 5% as wet materials.

Table 1. Composition of minerals of seaweeds. (%)

Item	Cavanaugh[a]	NRC[b]	SNU[c]
Macro Minerals:			
Sodium	4.00-10.00		
Chloride	13.37		
Calcium	1.00	2.00	
Phosphorus	0.34	0.20	0.16
Magnesium	0.74-0.10	7.12	0.90
Potassium	10.00-12.00	7.12	5.48
Sulfur	1.00		
Micro Minerals:			
Iron	0.04-0.10	0.058	
Iodine	0.19		
Copper	0.001-0.01		
Magnanese	0.01-0.10		
Zinc	0.001		
Aluminium	0.10		
Strondium	0.10		
Silicon	0.01-0.10		
Banadium	0.001		
Lead	0.001-0.01		
Titanium	0.0001-0.001		
Chrome	0.0001-0.001		
Barium	0.0001-0.001		
Silver	0.0001		

(a) : Professor of Cornell University, the results adopted from 'Folk Medicine' by Dr. D.C. Jarvis.

(b) : NRC,1977.

(c) : Seoul National University, Korea.

Carbohydrates in seaweeds include laminarin, algin, L-fucose, fucoidin and mannitol. Energy value of Gracilaria is 330 Kcal and Ulva lactuca is 250 Kcal. Black (1953) reported that small amount of mannitol are easily digested by rumen micro organisms in rumen and partly converted to glycogen but that large doses have a laxative effect. D-mannitol is excipient and diluent for solids and liquids. McNaugh et.al. (1954) found that laminarin was utilized by the rumen microflora but that it did not result in as great a synthesis of protein as with maltose. Fucoidin and L-fucose were used by the rumen microflora. Seaweeds contain invert sugar ranging 13.1-22.5% but simple sugars are present in low per cent.

Vitamins in seaweeds vary due to species, part of the alga, growing season, sea environment and sample preparation. Ericson and Lewis (1953) showed that Vitamins contain higher in the cell walls (0.2 μg/g) than the porpoplasm (less than 0.001 μg/ml.). They reported that some seaweed contain 1 μg of Vitamin B_{12}, the 'antipernicious anemia factor', per gram of dry weight. Thiamine 0.1 mg/kg, riboflavin 0.9 mg/kg and nicotinic acid 12 mg/kg were reported by Han (1976). Thivy (1958) found tocopherol, calciferol, folic acid and folinic aicd. Neela (Thivy) reported that the highest Vitamin C content was in Sargassum myriocystum 66.60 mg/100g of ground seaweed, and the lowest was 0.22 mg/100g of Enteromorpha prolifera. In Norway, Haug and Larsen (1956) on Fucaceae shows that to retain a high carotine content prolonged open air drying must be avoided and that rain is destructive; best results are obtained with artificial drying at 18°C. Storage for 3 to 4 months caused loss. Carotene and fucoxanthin are precursos of Vitamin A in seaweed. Han (1976) reported less than 5 IU/G of Vitamin A and 3.0 IU/G in Japanese seaweed.

Protein in seaweeds distributed from 5.6 to 15% in general. Ten essential amino acids and other amino acids have been reported as shown in the Table 2.

Table 2. Amino acids in seaweeds. (%)

Amino acids	NRC[a]	Han, Mokpo	Han, Pusan
Arginine	0.32	0.642	0.378
Histidine	0.10	0.158	0.121
Isoleucine	0.27	0.620	0.389
Leucine	0.48	1.051	0.647
Lysine	0.36	0.630	0.394
Methionine	0.07	0.341	0.164
Phenylalnine	0.27	0.657	0.426
Threonine	0.31	0.561	0.365
Tyrosine	0.15	0.349	0.231
Valine	0.39	0.794	0.490
Aspartic acid		1.541	0.973
Serine		0.507	0.337
Glutamic acid		2.354	1.728
Proline		0.590	0.361
Glycine		0.720	0.493
Alanine		0.947	0.566
Total:		12.462	8.063
EAAI		64.9	55.1

(a) : NRC, 1977.

Ten animo acids are reported by NRC (1977), twelve amino acids are recorded by Lewis et al. (1959) and Pillai (1957) and sixteen amino acids were reported by Han (1976). Protein sulphur in seaweed is extremely low of 0.01-0.04%. Amino acids in some species of seaweeds are occured as in the Table 3.

Schmidt (1944) recommended 2 Kg of starch pulp of sweet potatoes for cow per day, while Bielinski et al. (1954) reported 3 Kg of starch pulp for beef and milk cow. Gerry et al. (1951) reported that 6% and 4% (Han, 1970) of starch pulp could be replaced for chick ration. Stahl et al. (1932) showed that starch pulp was not palatable and resulted in poor growth for pig.

The present experiments were carried out to extend utilization of seaweeds and starch pulp resources for ruminant animal feedstuffs and to improve storaging and feeding efficiencies by combining these two resources.

Materials and Methods

Seaweeds were collected from Hwasoon district, Jeju. Seaweeds were Sargassum thumbergii O. Kuntze, S. Serratiflium C. Agardb and S. Ringglidia um Harvey. These inedible seaweeds were washed and air dried to grind through 0.5 mm screen. The sweet potatoe starch pulp produced at a Pobho-Chon starch manufacturing factory was used. Starch pulp containing 97.2% of moisture was dried in an over at 85°C for 24 hours to grind through 0.5 mm sieve.

The chemical compositions of thses two samples are shown in the Table 5.

The dried seaweed meal was replaced at various rates of 0%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. Eighty grams of each treatment mixtures were allocated into 100 ml. flasks to evaporate in an open air. Degrees of evaporation were calculated by the weight differences from oven drying for 12 hours, 24 hours, 48 hours, 72 hours and 96 hours. The dry conditions were temperature ranging from 5.8°C to 18.4°C with mean value of 12.1°C, average

Table 3. Occurrence of amino acids in green, brown and red seaweeds.

	Common	Occasional	Scarce
Green Algae	Serine, Glycine Arginine, Threonine Alanine, Glutamine Proline, Valine Aspartic acid Glutamic acid Leucine, Isoleucine Cystine, Unclass.	Asparagine Ornithine Lysine Citrulline Tyrosine Phenylalnine Unclass.	β-alanine Methionine Cysteic acid Unclass.
Brown Algae	Serine, Glycine Arginine, Threonine Alanine, Glutamine Proline, Valine Aspartic acid Glutamic acid Leucine, Isoleucine Unclass.	Asparagine Ornithine Lysine Tyrosine Phenylalnine Cystine Unclass.	Citrulline β-alanine Methionine Cysteic acid Unclass.
Red Algae	Aspartic acid, Serine Glutamic acid, Glycine Arginine, Ornithine Threonine, Alanine Tyrosine, Proline Valine, Leucine Isoleucine, Unclass.	Asparagine Glutamine Lysine Phenylalnine Cystine Unclass.	Citrulline β-alanine Methionine Unclass.

Nutrient contents and evaluation of sweet potatoes starch pulp are shown in the Table 4.

Table 4. Nutrient contents of sweet potatoes starch pulp.

Nutrients	Unit	SNU[(a)]	NRC	JAPAN
Chemical Composition:				
Moisture	%	9.59	9.8	16.1
Crude protein	%	4.49	2.5	2.7
Crude Fat	%	1.91	0.3	0.8
Crude Fiber	%	18.73	9.6	15.2
N.F.E.	%	44.52	71.8	61.2
Ash	%	20.76	6.0	4.0
Digestible Nutrients:				
DCP (pig)	%	1.24	–	–
TDN (cattle)	%	–	67.6	60.0
TDN (sheep)	%	–	71.8	–
TDN (pig)	%	61.94	68.2	56.6
DE (cattle)	Mcal/kg	–	2.98	–
DE (sheep)	Mcal/kg	–	3.17	–
DE (pig)	Kcal/kg	–	3,006	–
ME (cattle)	Mcal/kg	–	2.44	–
ME (sheep)	Mcal/kg	–	2.60	–
ME (pig)	Kcal/kg	–	2,868	–
Minerals:				
Calcium	%	0.91		
Phosphorus	%	0.81		

(a) : Han (1976).

Table 5. Chemical composition of the seaweeds and starch pulp.

Ingredients	Seaweeds	Starch pulp	
	%	%	%
Moisture	14.9	97.20[a]	13.11[b]
Crude protein	6.5	0.23	6.76
Ether extracts	4.2	0.05	1.11
Crude fiber	7.9	1.19	66.67
Nitrogen free extracts	48.6	0.19	8.23
Ash	17.9	0.14	4.12

(a) : West starch pulp.
(b) : Dried starch pulp.

humidity 70.2%, average evaporation degree 2.5 mm, rate of sunny per day 58.6% and the maximum wind speed 5.1 m/sec. The chemical analysis was done by the methods of A.O.A.C. (1975).

The rumen fluid was collected from a Korean native goat. In the experiment 2, the seaweed and starch pulp samples used were similar to that of the experiment 1. The *in vitro* fermentation techniques applied in this experiment was the method proposed by Tilley and Terry (1963) modified as suitable for Korean laboratory conditions by Lee (1971).

Results and Discussion

For the 12 hours of drying period, the highest value was found as the 60% seaweed meal treatment lot followed by the 70% seaweed lot, 50% seaweed lot and 40% seaweed lot with evaporation values of 1.21%, 1.16%, 1.13% and 1.02% respectively.

For the 48 hours of drying, the highest value was the 10% seaweed treatment lot with 9.45% of evaporation followed by 9.42% in the 20% seaweed lot.

For the 72 hours of drying period, the evaporation values were 11.45% in the 10% seaweed lot, 10.6% in the 20% seaweed lot, 7.72% in the 30% seaweed lot and 7.33% in the 0% lot. Those lots of 0%, 10% and 20% seaweed treatment showed steady increase until 96 hours of dry period.

Table 6. The rates of evaporation in the various levels of replaced seaweed meal for sweet potatoes starch pulp at some drying periods. (%)

Levels of seaweed replaced.	Moisture	Drying periods (hrs)					Total evap.
		12	24	48	72	96	
0%	97.17%	0.69	2.11	5.40	7.33	9.02	25.41
10	89.07	0.90	3.91	9.45	11.45	12.39	40.00
20	80.98	0.98	4.19	9.42	10.60	11.02	38.32
30	72.89	0.95	4.01	7.63	7.72	6.97	29.21
40	64.80	1.02	3.56	6.27	6.48	5.66	25.15
50	56.70	1.13	3.44	5.87	5.56	4.97	23.10
60	48.61	1.21	2.82	4.77	4.92	4.11	19.67
70	40.52	1.16	2.57	4.39	4.62	3.60	18.04
80	32.42	0.96	1.30	3.70	4.26	3.15	14.77
90	24.33	0.82	1.77	3.04	3.62	2.42	12.95
100	16.24	0.25	1.17	2.09	2.83	1.84	8.80

For the total evaporation rates, the highest result was the 10% seaweed treatment lot followed by the 20%, 30%, 0%, 40%, 50%, 60%, 70%, 80%, 90% and the 100% treatment lot. The optimum levels of dry seaweed meal addition to wet starch pulp were ranged between 10%-30%.

For practical application, the bad smell produced by wet starch pulp stored for a long period of time could be disappeared by adding seaweed meal at 10% level while the control lot produced bad smell. The dewatering effects were effective by addition of seaweed meal to wet starch pulp at economical proportions.

For the *in vitro* dry matter digestibility (DDM) and the *in vitro* organic matter digestibility the most optimum proportion between seaweed meal and starch pulp was the 40% seaweed meal mixed with 60% starch pulp treatment lot. For the digestible organic matter the 30% seaweed meal lot was found the highest. These are shown in the Table 7 and figured in the Fig. 1.

There were statistical significant interactions ($P < 0.05$) between *in vitro* results and the theoretical digestibilities of organic matter of seaweed and starch

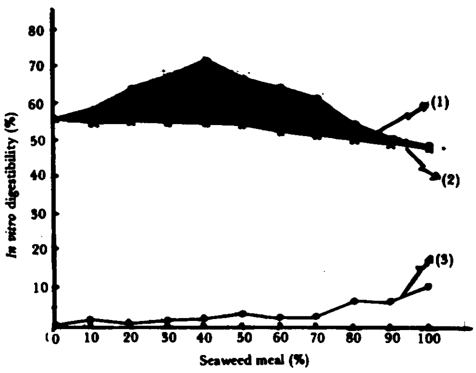

Fig. 1. ***In vitro* digestibility of various mixtures of seaweed meal with sweet potatoes starch pulp by Korean goat.**

(1) : Digestible dry matter.
(2) : Theoretical digestible dry matter.
(3) : Digestibility of ash.

Table 7. *In vitro* digestibilities of the various mixtures of seaweed meal with sweet potatoes starch pulp by Korean goat. (%)

Sea weed (D.M.) vs Starch pulp (D.M.)	DDM[(a)]	TDDM[(b)]	OMD[(c)]	TOMD[(d)]	DOM[(e)]	TDOM[(f)]	Dig. ash
0:100	56.4	56.4	56.0	56.0	53.7	53.7	0.61
10: 90	58.7	55.8	59.8	54.7	55.4	51.3	1.93
20: 80	65.0	55.2	64.5	53.4	58.9	48.9	0.56
30: 70	68.7	54.6	68.2	52.0	60.3	46.6	1.48
40: 60	71.3	54.0	70.6	50.7	59.6	44.2	2.01
50: 50	67.9	53.4	66.4	49.4	55.7	41.8	3.80
60: 40	64.2	52.8	62.9	48.0	50.4	39.4	2.70
70: 30	62.2	52.2	60.6	46.8	47.4	37.0	3.18
80: 20	54.9	51.6	49.6	45.4	37.4	34.7	8.75
90: 10	52.3	51.0	46.7	44.1	34.0	32.3	8.39
100: 0	50.4	50.4	42.8	42.8	29.9	29.9	10.78

(a) : Digestible Dry Matter $= \frac{\text{Digested Dry Matter}}{\text{Sample Dry Matter}} \times 100$

(b) : Theoretical Value of DDM

(c) : Organic Matter Digestibility $= \frac{\text{Digested O.M.}}{\text{Sample D.M.}} \times 100$

(d) : Theoretical Value of OMD

(e) : Digestible Organic Matter $= \frac{\text{Digested O.M.}}{\text{Sample O.M.}} \times 100$

(f) : Theoretical Value of DOM

pulp in all the treatment lots statistically analyzed by Chi-square test.

In *in vitro* digestible organic matter the highest value was by the 30% seaweed meal lot followed by the 40% seaweed meal lot, the 20% seaweed lot and the 50% seaweed meal lot.

To promote the digestibilities of both seaweed and starch pulp, these two resources should be mixed simultaneously at 30% or 40% of seaweed with starch pulp. This results coincide with the results reported by Lee (1976) in that seaweed should be mixed with other bulky organic materials in proper rates for ruminant as illustrated in the Fig. 1. In the Fig. 1, the area between 1 (DDM) and 2 (TDDM) may be expressed as the product of interactions occurred during *in vitro* fermentation of seaweed meal and sweet potato starch pulp.

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國 文 抄 錄

濟州産 生澱粉粕이 소비자에게 공급될 때 까지는 野外에 積置된 상태에 있어 시간이 경과됨에 따라서 悪臭가 발생되며 運送이 곤란하다. 本 試験은 飼料資源의 하나인 澱粉粕을 有利하게 活用하기 위하여 또하나의 飼料資源인 不可食性 海藻粉을 混合하여 生澱粉粕의 乾燥速度를 加速시키고 同時에 悪臭대신 香臭를 発生케하여 単用時 보다 混合給与時 反芻家畜이 消化率을 交互的으로 増進하는 効果를 높이고저 하는 데 目的이 있었다.

試験 1에서는 海藻粉과 澱粉粕의 混合 水準別 試験処理区間의 水分蒸発率을 調査하였고, 試験 2에서는 이들 2個 飼料資源間의 混合比率이 反芻家畜에 의한 *in vitro* 乾物 消化率, 有機物 消化率, 灰分 消化率을 調査하였다.
試験 1의 試験結果에 의하면 最高 蒸発率은 10％ 海藻粉 処理区이였고, 다음이 20％ 海藻類粉 処理区, 및 30％海藻粉 処理区였다. 따라서 10％ 海藻粉 混合区는 経済的이면서 混合物의 香気를 현저하게 改善하였을 뿐만 아니라 日光・風乾에 의한 自然 乾燥効果를 상승시켰다고 본다.

試験 2에서, *in vitro* 乾物消化率이 가장 높은 処理区는 海藻粉 40％와 澱粉粕 60％ 混合区였다. *in vitro* 有機物 消化率은 30％ 海藻粉 処理区에서 최고 수준을 보였다. 모든 処理区의 *in vitro* 消化率에서 両飼料資源間에 統計的 交互作用($p < 0.05$)을 보였다.