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Maximizing Vitamin Retention in Extruded Dry Pet Food

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HEALTH · NUTRITION · MATERIALS

Overview

- Vitamins
- Vitamin product forms
- Vitamin stability during extrusion
- Maximizing vitamin retention

Vitamins

~30% of cat essential nutrients (13/44)

<0.012% by weight in a complete cat food on dry matter

3.2.3. Recommended nutrient levels for complete cat food

TABLE III-4a.

Unit per 100 g dry matter (DM)

Nutrient	UNIT	Minimum Recommended Level			Maximum
		Adult based on MER of		Growth / Reproduction	(L) = EU legal limit
		75 kcal/kg	100 kcal/kg		(N) = nutritional
Protein*	g	33.30	25.00	28.00/30.00	-
Arginine*	g	1.30	1.00	1.07/1.11	Growth: 3.50 (N)
Histidine	g	0.35	0.26	0.33	-
Isoleucine	g	0.57	0.43	0.54	
Leucine	g	1.36	1.02	1.28	
Lysine*	g	0.45	0.34	0.85	
Methionine*	g	0.23	0.17	0.44	Growth: 1.30 (N)
Methionine + cystine*	g	0.45	0.34	0.88	
Phenylalanine	g	0.53	0.40	0.50	
Phenylalanine + tyrosine*	g	2.04	1.53	1.91	
Threonine	g	0.69	0.52	0.65	
Tryptophan*	g	0.17	0.13	0.16	Growth: 1.70 (N)
Valine	g	0.68	0.51	0.64	
Taurine (canned pet food)*	g	0.27	0.20	0.25	
Taurine (dry pet food)*	g	0.13	0.10	0.10	
Fat*	g	9.00	9.00	9.00	
Linoleic acid (ω-6)	g	0.67	0.50	0.55	
Arachidonic acid (ω-6)	mg	8.00	6.00	20.00	
Alpha-linolenic acid (ω-3)*	g	-	-	0.02	
EPA + DHA (ω-3)*	g	-	-	0.01	
Minerals					
Calcium*	g	0.53	0.40	1.00	
Phosphorus*	g	0.35	0.26	0.84	
Ca/P ratio			1/1		Growth: 1.5/1 (N) Adult: 2/1 (N)
Potassium	g	0.80	0.60	0.60	
Sodium*	g	0.10	0.08	0.16	
Chloride	g	0.15	0.11	0.24	
Magnesium*	g	0.05	0.04	0.05	
Trace elements*					
Copper*	mg	0.67	0.50	1.00	2.80 (L)
Iodine*	mg	0.17	0.13	0.18	1.10 (L)
Iron*	mg	10.70	8.00	8.00	68.18 (L)
Manganese	mg	0.67	0.50	1.00	17.00 (L)
Selenium (wet diets)	µg	35.00	26.00	30.00	56.80 (L)
Selenium (dry diets)	µg	28.00	21.00	30.00	56.80 (L)
Zinc	mg	10.00	7.50	7.50	22.70 (L)
Vitamins					
Vitamin A*	IU	444.00	333.00	900.00	Adult & Growth: 40 000 (N) Reproduction: 33 333 (N)
Vitamin D*	IU	33.30	25.00	28.00	227 (L) 3 000 (N)
Vitamin E*	IU	5.07	3.80	3.80	
Vitamin B1 (Thiamine)*	mg	0.59	0.44	0.55	
Vitamin B2 (Riboflavin)	mg	0.42	0.32	0.32	
Vitamin B5 (Pantothenic acid)	mg	0.77	0.58	0.57	
Vitamin B6 (Pyridoxine)*	mg	0.33	0.25	0.25	
Vitamin B12 (Cyanocobalamin)*	µg	2.35	1.76	1.80	
Vitamin B3 (Niacin)*	mg	4.21	3.20	3.20	
Vitamin B9 (Folic acid)*	µg	101.00	75.00	75.00	
Vitamin B7 (Biotin)*	µg	8.00	6.00	7.00	
Choline	mg	320.00	240.00	240.00	
Vitamin K*	µg	-	-	-	

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What is a Vitamin?

- Organic compounds
- Essential to metabolism
- Small amount required
- Body can’t make or make enough
- Obtain vitamins through food

Vitamin D deficiency

http://katiediazz.myblog.arts.ac.uk/2016/02/21/research-sunday-rickets-disease/

Thiamin deficiency

http://www.dsm.com/markets/anh/en_US/Compendium/companion_animals/thiamin.html

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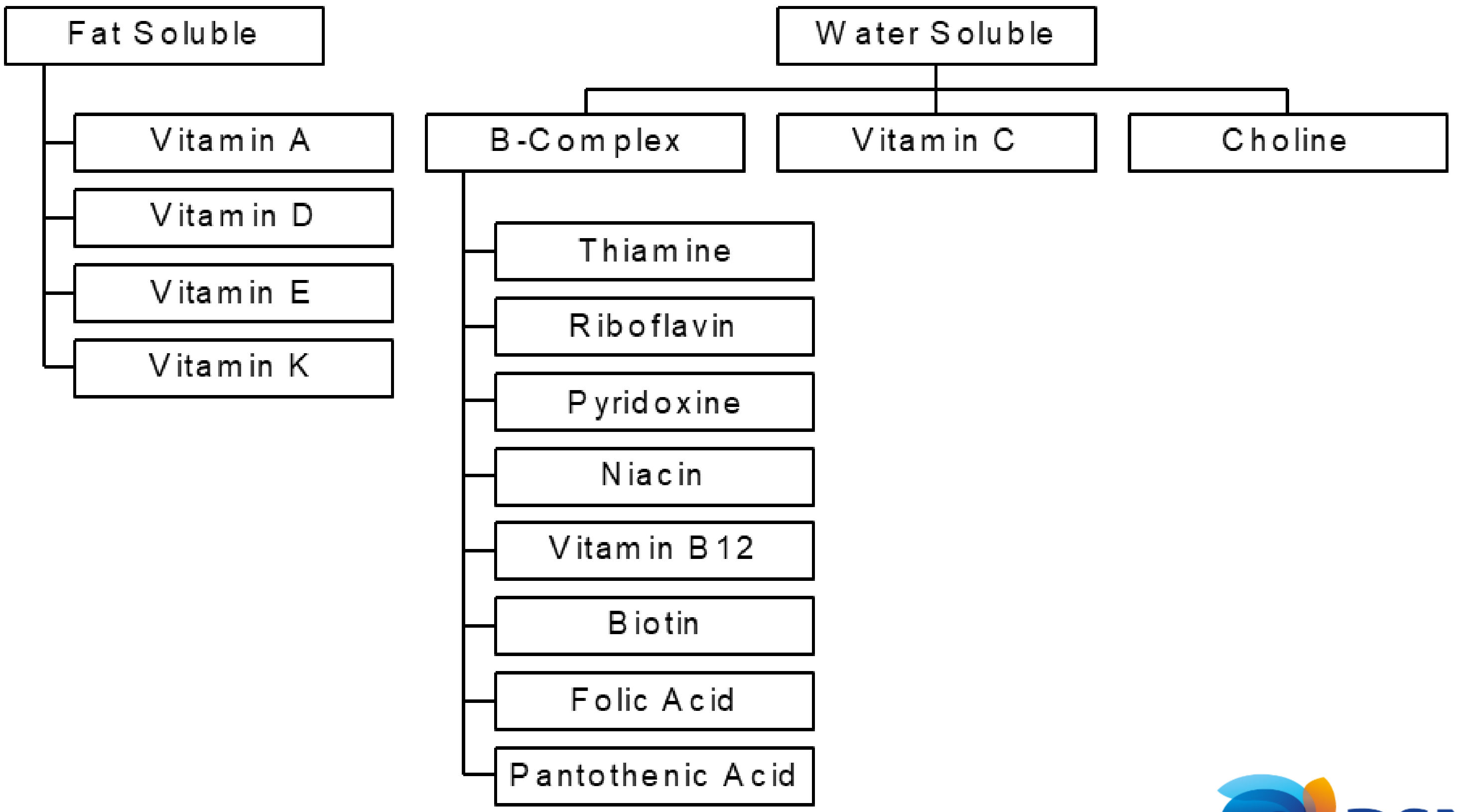
Vitamins



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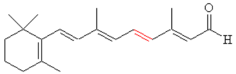
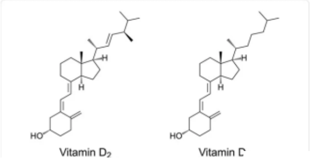
Basic Vitamin Compounds

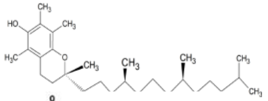
- Vitamin A - Retinol



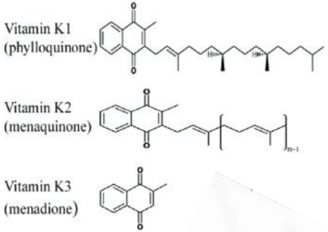
- Vitamin D – Cholecalciferol (D_3), Ergocalciferol (D_2)



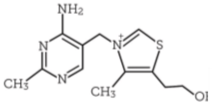
- Vitamin E - Alpha-tocopherol



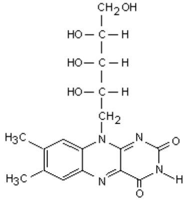
- Vitamin K - Phylloquinine(K_1), Menaquinones (K_2), Menadione(K_3)



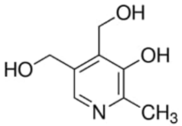
- Vitamin B_1 - Thiamine



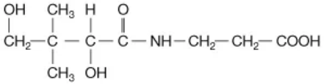
- Vitamin B_2 - Riboflavin



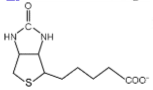
- Vitamin B_6 - Pyridoxine



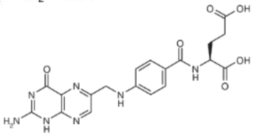
- Pantothenic Acid



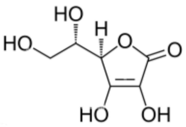
- Biotin



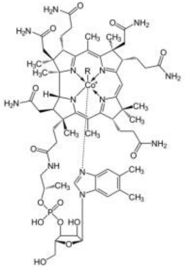
- Folic Acid

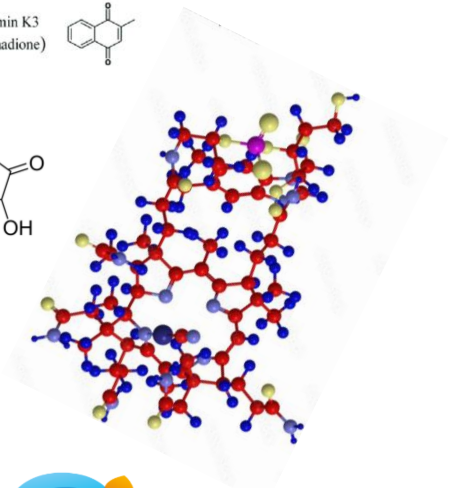


- Vitamin C - Ascorbic Acid

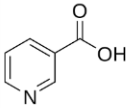


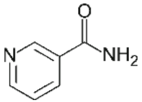
- Vitamin B_{12} - Cyanocobalamin





- Niacin/Niacinamide





They may not be suitable forms for pet food applications

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Factors Affecting the Stability of Vitamins in Basic Forms

Vitamin	Heat	Oxidation	Moisture	Light	Acid	Alkali	Radiation
Vitamin A	++	++	+	++	+	0	++
Vitamin D_3	+	++	+	++	+	+	+
Vitamin E	0	+	0	+	0	+	+
Vitamin K_3	++	+	++	++	0	++	0
Thiamine	++	+	+	+	0	++	0
Riboflavin	0	0	+	++	0	++	+
Pyridoxine	++	0	+	+	+	+	+
Vitamin B_{12}	++	+	+	+	++	++	+
Pantothenic acid	+	0	+	0	++	++	0
Niacin	0	0	0	0	0	0	0
Biotin	+	0	0	0	+	+	0
Folic acid	++	0	+	+	+	+	++
Vitamin C	++	++	++	0	0	++	0

++: Marked effect   +: Moderate effect   0: No effect

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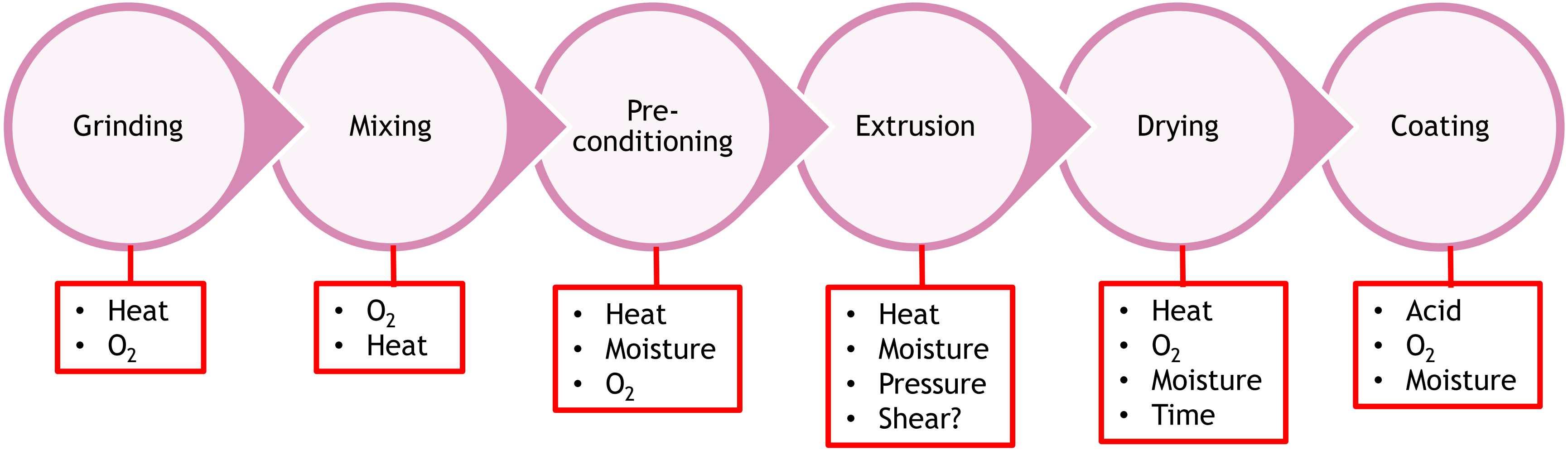
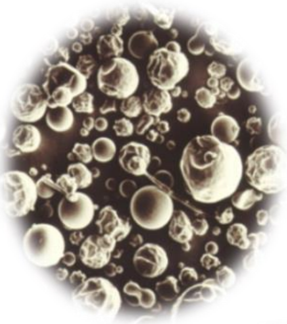
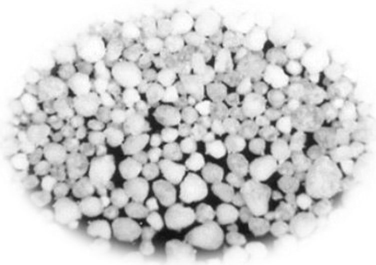
Extrusion process of a dry pet food

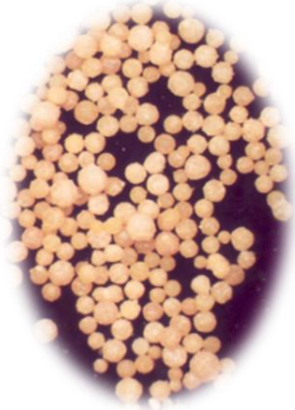


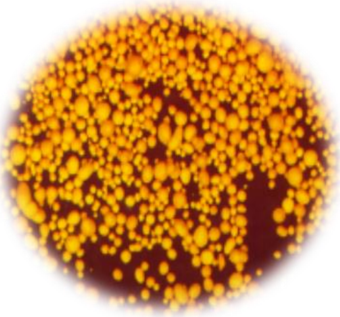
Vitamin product forms are developed to address:

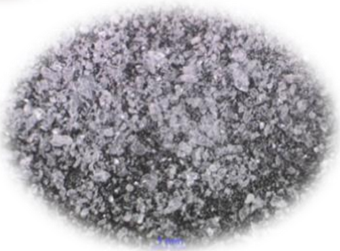
- Stability
- Handling
- Other needs

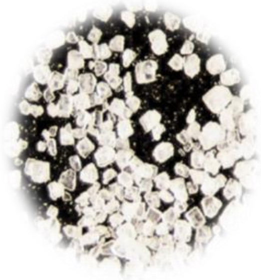












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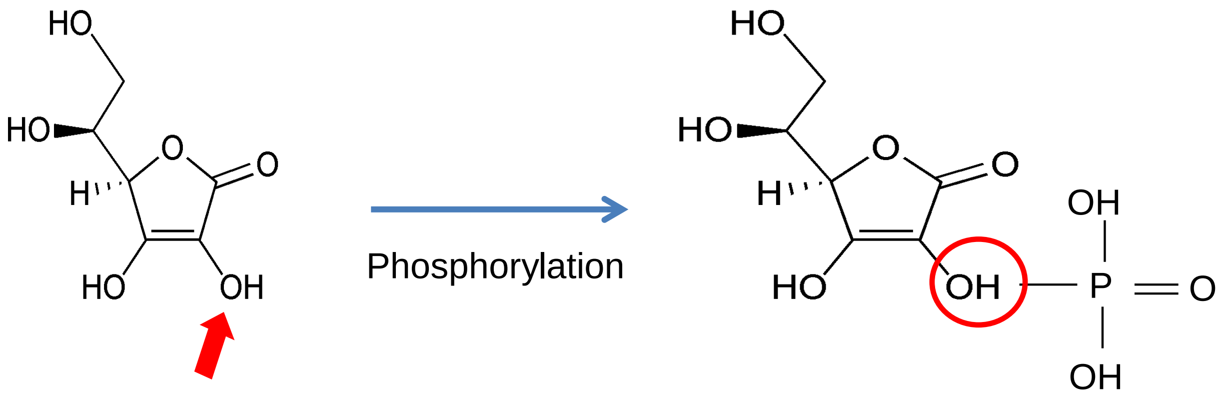
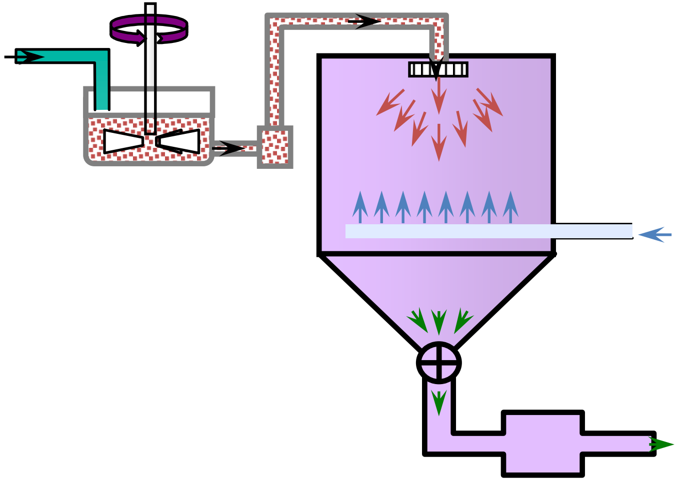
Chemical Modification – Phosphorylation

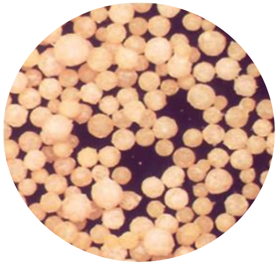


Ascorbic acid

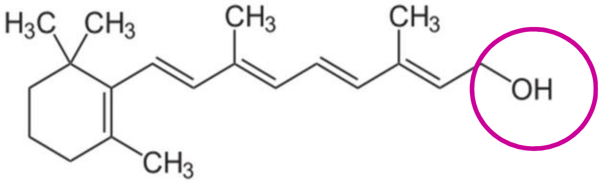
Ascorbyl-2-Monophosphate

Physical Modification

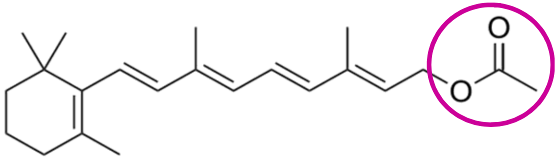




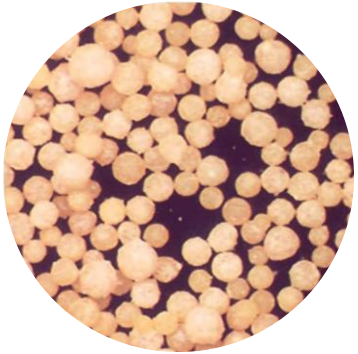
Chemical & Physical Modifications



Retinol



Retinyl Acetate



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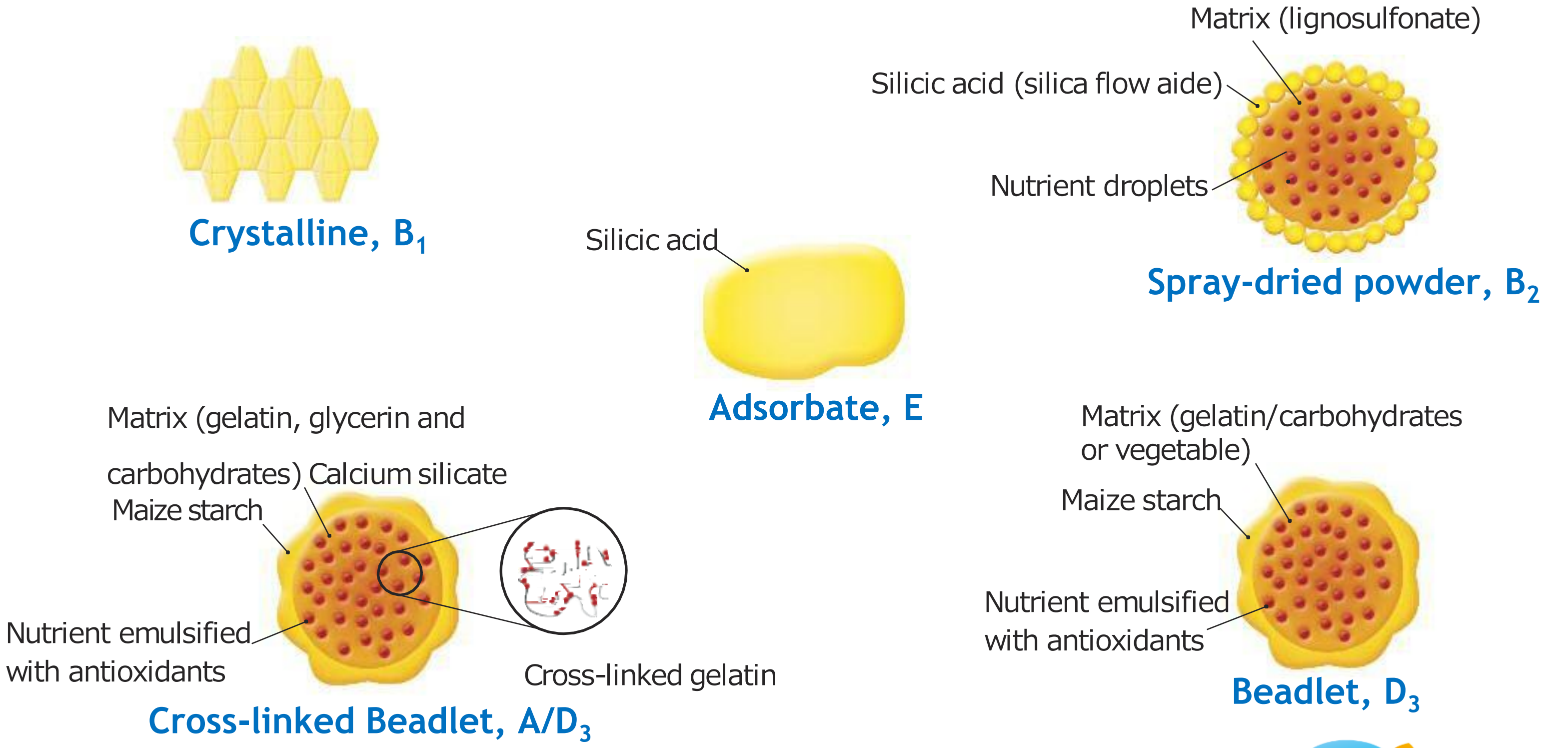
Common Vitamin Product Forms



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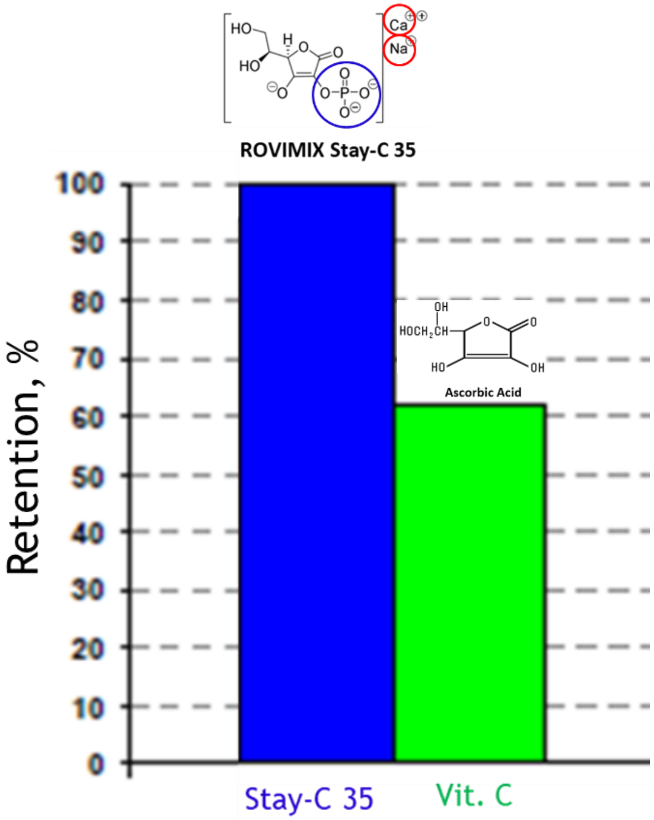
Stability of Different Vitamin C Forms During Extrusion



Trial VFP 24059

Stability of Different Vitamin K_3 Forms During Extrusion

Table 1. Effects of sources and formulations of vitamin K_3 and extrusion temperature on its stability.

	Source (A)		Formulation (B)			Temperature (C)			*p*-Values						
	MSB	**MNB**	**Cr**	**Mic-c**	**Mic-s**	**LT**	**HT**	**SEM**	**A**	**B**	**C**	**A × B**	**A × C**	**B × C**	**A × B × C**
Sample size (n)	54	54	36	36	36	54	54								
VK_3 recovery (%)	64.67^{B}	72.74^{A}	74.16^{a}	65.25^{b}	66.72^{b}	70.88^{α}	66.54^{β}	0.81	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.307

^{A,B} Means in a row, with different superscripts, are different ($p < 0.05$) under source. ^{a,b} Means in a row, with different superscripts, are different ($p < 0.05$) under formulation. $^{\alpha,\beta}$ Means in a row, with different superscripts, are different ($p < 0.05$) under temperature. MSB, menadione sodium bisulfite; MNB, menadione nicotinamide bisulfite; Cr, crystal; Mic-c, micro-capsule; Mic-s, micro-sphere; LT, low temperature (100 °C); HT, high temperature 7(135 °C); VK_3, vitamin K_3; SEM, Standard Error of Mean; A, Source; B, Formulation; C, Temperature.

MSB: menadione sodium bisulfite
- Cr: Crystal
- Mic-c: Micro-capsule (stearic acid & glycerate)
- Mic-s: Micro-sphere (carboxymethyl cellulose & ethyl cellulose)

MNB: Menadione nicotinamide bisulfite
- Cr: Crystal
- Mic-c: Micro-capsule (stearic acid & glycerate)
- Mic-s: Micro-sphere (carboxymethyl cellulose & ethyl cellulose)

LT: Low temperature (100°C)

HT: High temperature (135°C)

Wang et al., 2021

Stability of Different Vitamin K_3 Forms

Unstable

Menadione Sodium Bisulfite	50% Menadione
Menadione Sodium Bisulfite Complex	33% Menadione
Menadione Pyrimidinol Bisulfate	45% Menadione
Menadione Nicotinamide Bisulfite	46% Menadione

Stable

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Stability of Fat Microencapsulated Vitamins during Extrusion

Table 5. Effects of extruded temperature (Temp.) and vitamin forms (non-microencapsulated or microencapsulated) on the percentage of vitamins in diets (Experiment 1) [1].

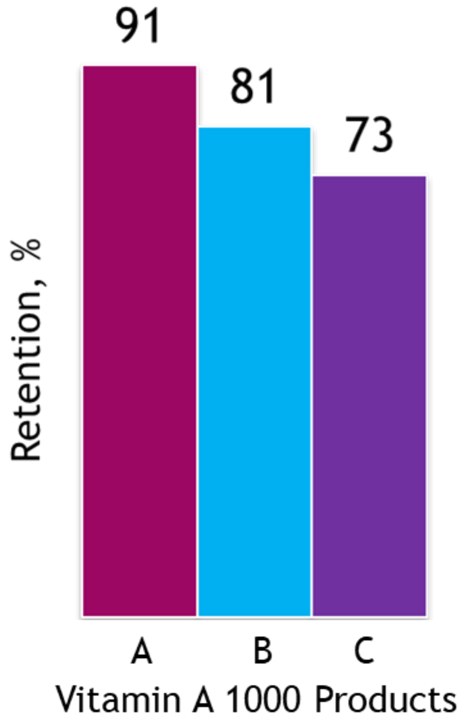
Form	Temp.	VA	VD_3	VE	VK_3	VB_1	VB_2	VB_3	VB_5	VB_6
NM	100 °C	46.34	73.94	47.34	7.17	94.91	98.71	102.59	99.19	74.35
	140 °C	34.75	53.14	42.23	6.12	79.24	87.77	89.75	84.32	78.12
	180 °C	30.76	40.26	45.17	11.64	78.31	90.16	87.18	85.51	71.82
M	100 °C	56.41	75.73	49.17	48.04	100.71	105.16	104.81	100.83	101.88
	140 °C	40.25	56.86	43.09	35.20	83.81	91.39	90.59	87.47	92.46
	180 °C	41.80	60.74	46.41	38.55	83.60	90.76	90.20	84.41	89.25
SEM		0.74	3.40	1.10	1.81	0.68	1.28	1.14	1.75	3.16
Main effects										
Form	NM	37.28	55.78	44.91	8.31	84.15^{y}	92.21^{y}	93.18^{y}	89.67	74.76^{y}
	M	46.15	64.44	46.22	40.60	89.37^{x}	95.77^{x}	95.20^{x}	90.90	94.53^{x}
Temp.	100 °C	51.37	74.83	48.26^{a}	27.60	97.81^{a}	101.93^{a}	103.70^{a}	100.00^{a}	88.11
	140 °C	37.50	55.00	42.66^{b}	20.66	81.52^{b}	90.46^{b}	90.17^{b}	85.90^{b}	85.29
	180 °C	36.28	50.50	45.79^{a}	25.10	80.96^{b}	89.58^{b}	88.69^{b}	84.96^{b}	80.54
p-value										
Form		<0.001	0.015	0.154	<0.001	<0.001	0.002	0.038	0.397	<0.001
Temp.		<0.001	<0.001	< 0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.069
Form × temp.		<0.001	0.035	0.905	0.001	0.667	0.09	0.110	0.478	0.110
Significant *p*-values for contrasts										
NM 100 °C vs. M 100 °C		<0.001	-	-	<0.001	-	-	-	-	-
NM 140 °C vs. M 140 °C		<0.001	-	-	<0.001	-	-	-	-	-
NM 180 °C vs. M 180 °C		<0.001	<0.001	-	<0.001	-	-	-	-	-
NM 100 °C vs. NM 140 °C		<0.001	<0.001	-	-	-	-	-	-	-
NM. 100 °C vs. NM 180 °C		<0.001	<0.001	-	-	-	-	-	-	-
NM 140 °C vs. NM 18 0 °C		<0.001	0.013	-	0.039	-	-	-	-	-
M 100 °C vs. M 140 °C		<0.001	0.011	-	<0.001	-	-	-	-	-
M 100 °C vs. M. 180 °C		<0.001	0.037	-	<0.001	-	-	-	-	-
M 140 °C vs. M 180 °C		-	-	-		-	-	-	-	-

[1] Main effects are shown for responses in which the interaction was not significant, whereas contrasts are shown where a significant interaction was detected. VA; vitamin A, VD_3; vitamin D_3, VE; vitamin E, VK_3; vitamin K_3, VB_1; vitamin B_1, VB_2; vitamin B_2, VB_3; vitamin B_3, VB_5; vitamin B_5, VB_6; vitamin B_6. [x, y] Means within a column that lack a common superscript differ ($p < 0.05$). [a, b, c] Means within a column that lack a common superscript differ ($p < 0.05$). NM, non-microencapsulated; M, microencapsulated. The changes in vitamin concentration during extrusion are presented in Table S1.

M: Vitamins microencapsulated with hydrogenated fat

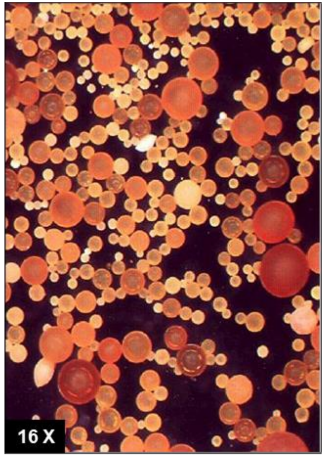
Yang et al., 2020

Stability of Vitamin A from Different Manufacturers during Extrusion

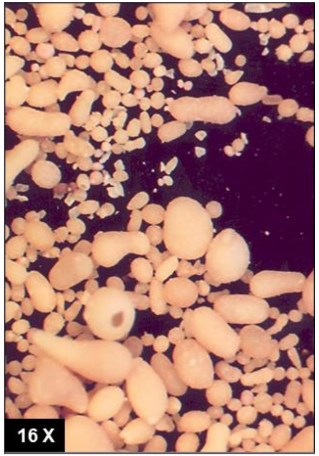


Source: Trial vfp201070

Product A



Product B



Product C

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Stability of Vitamins in Different Pet Food during Extrusion

Table 3.3: The effects of experimental protein level (low, medium and high) on vitamin retention exiting the extruder, as-is basis.

			Protein Level (%)				
Item	Unit	Target*	Low (24)	Medium (27)	High (34)	SEM	*P*=
Vitamin A	IU/kg	241,014.0	206,249.0[b]	219,184.0[a]	225,352.0[a]	3,791.4	0.020
Vitamin D_3	IU/kg	10,205.0	7,836.0	8,204.0	8,377.0	215.8	0.260
Vitamin E	IU/kg	1,269.0	755.0[c]	801.0[b]	893.0[a]	32.0	0.050
Folic Acid	mg/kg	2.3	1.4[b]	1.6[b]	1.8[a]	0.05	0.004
Thiamine	mg/kg	28.2	22.5	23.3	23.6	0.36	0.200

[ab] Means in a row with unlike superscripts differ ($P < 0.05$).

*Target was not evaluated in statistical analysis and is provided as a form of reference for the target amount intended based on vitamins in premix.

Mooney, 2010

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Stability of Vitamins in Different Pet Food during Drying

Table 3.4: The effects of experimental crude protein level on vitamin retention as kibble exits the drier.

Item	Unit	Target*	Protein Level (%)			SEM	*P*=
			Low(24)	Medium(27)	High(34)		
Vitamin A	IU/kg	241,014.0	173,022.0	173,234.0	171,069.0	3,521.9	0.80
Vitamin D_3	IU/kg	10,205.3	6,945.7[b]	7,472.6.0[b]	9,047.1[a]	458.1	0.006
Vitamin E	IU/kg	1,269.1	894.7[b]	884.8[b]	1,102.3[a]	26.6	0.001
Folic Acid	mg/kg	2.3	1.8[b]	1.9[b]	2.2[a]	0.03	0.0006
Thiamine	mg/kg	28.2	25.5	25.1	26.6	0.6	0.14

[ab] Means in a row with unlike superscripts differ ($P < 0.05$).

*Target was not evaluated in statistical analysis and is provided as a form of reference for the target amount intended based on vitamins in premix.

Mooney, 2010

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Stability of Vitamins at Different Temperature during Extrusion

Table 7 Effect of extrusion temperature on different vitamins stability.

Fat-Soluble Vitamins	91–95°C	141–145°C	% Loss from 95 to 145°C
A, beadlet	90	62	25.2
D, beadlet	96	86	9.6
E, acetate	95	81	13.3
Water-Soluble Vitamins			
Thiamine HCL	90	50	36
Riboflavin	98	91	7.1
B6	93	73	18.6
B12	97	86	10.67
Pantothenic acid	94	75	17.86
Folic Acid	93	64	26.97
Biotin	93	63	27.9
Niacin	92	64	25.7
Vitamin C	57	5	91.22

Source: BASF Documentation DC 0002.

Riaz et al, 2009

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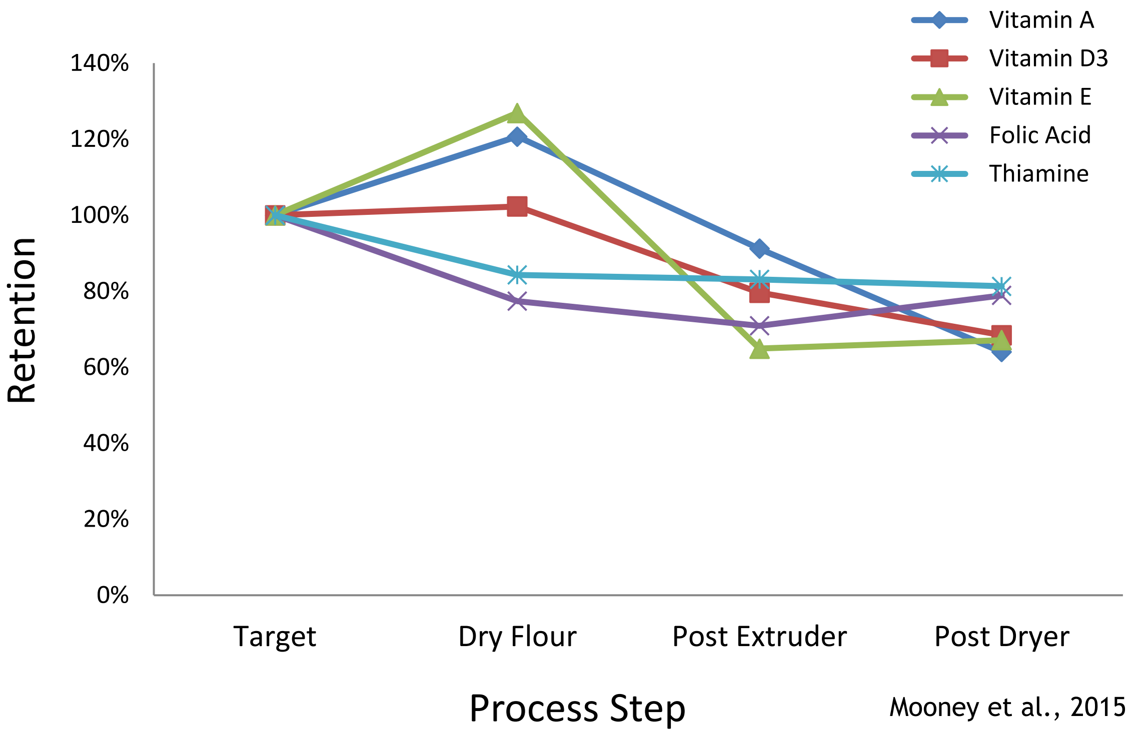
Stability of Vitamin A, D_3, E, Folate, and B_1 during Extrusion



Mooney et al., 2015

Effect of Extrusion Process Conditions on Vitamin Stability

Table 2 Extrusion parameters that increase vitamin destruction.

↑	Barrel and mass temperature
↑	Screw speed
↑	Specific energy input
↓	Feed moisture
↓	Die diameter
↑	Throughput

Source: Killeit (1994).

Riaz et al, 2009

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Vitamin Retention during Extrusion

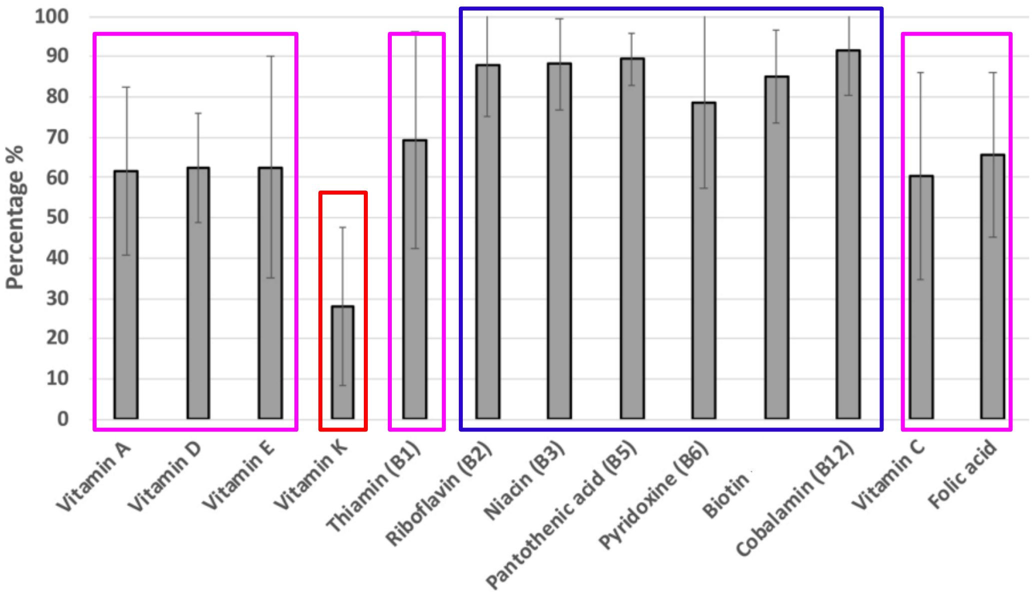

Fig. 1. Average retention of vitamins under various extrusion processes and food matrixes. Based on the work of Mustakas et al. (1964), 1970; Beetner et al. (1974), 1976; Lee et al. (1978); Maga and Sizer (1978); Lorenz et al. (1980); Bjorck and Asp (1983); Killeit and Wiedmann (1984); Andersson and Hedlund (1990); Guzman-Tello and Cheftel (1990); Killeit (1994); Andersson and Sunderland (2002); Cha et al. (2003); Athar et al. (2006); Plunkett and Ainsworth (2007); Ilo and Berghofer (2008); Tran et al. (2008); Riaz et al. (2009); Boyaci et al. (2012); Emin et al. (2012); Ying et al. (2015); Alam et al. (2016); Bajaj and Singhal (2019); Yang et al. (2020).

Morin et al., 2021

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Summary

- Vitamins are essential for dogs and cats.
- Vitamins are a group of organic compounds, and they are prone to the process and storage losses.
- To maximize vitamin retention during extrusion, proper forms and high quality of vitamin products should be used.
- Reducing (Thermal Energy + Mechanic Energy) x Time helps to improve vitamin retention during process of extruded dry pet food.

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Thank You

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