

## 授課講師學經歷

姓名	趙振瑞
課程名稱(主題)	母乳的營養與嬰兒副食品
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經歷	臺北醫學大學保健營養學系教授、國際學術交流中心主任

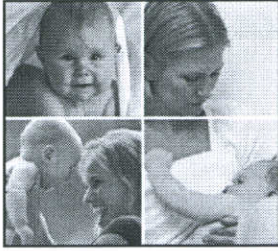
## 授課內容摘要

母乳依產後分泌時間分為初乳、過渡乳，及成熟乳，特別是初乳具有許多較高濃度與生長發育有關之調節因子，如乳鐵蛋白、分泌型免疫球蛋白 A (secretory IgA; sIgA)、生長因子，而這些調節因子會隨產後時間增長而減少於母乳中之濃度。母乳中有許多調節因子，如抗微生物因子、抗發炎因子、免疫調節因子，這些調節因子可能會受飲食因素而影響其濃度。

哺乳期間母親的營養狀態會影響母乳品質，進而影響餵補母乳寶寶的營養狀態。研究發現母體攝取的營養素會影響母乳品質與分泌量，母乳中的某些營養素含量，會因母親在飲食中增加攝取而增加，像是如蛋白質、維生素 A、維生素 B 群、維生素 E、錳、碘、鎂等。哺乳期間適當減重婦女，每天平均減少 538 大卡，並不會影響母乳分泌量與品質。但對中度營養不良的哺乳婦女每天增加 500 大卡熱量攝取者較每天僅增加 140 kcal 熱量攝取者明顯增加母乳中 sIgA 含量，對乳鐵蛋白含量則無影響。降低肉類、蛋、乳製品，及高油脂食物攝取量，而增加米飯、蔬菜、豆類，及海草攝取量會降低 2~5 個月產後婦女母乳中總蛋白質含量。

雞精為一種傳統高蛋白補充品，由於其所含蛋白質分子量較小，因此較易被人體吸收。本研究目的探討懷孕後期(37 週)至產後 3 天補充雞精對哺乳婦女乳汁蛋白組成的影響。於婦產科門診篩選，並經婦產科主治醫師確定為健康產婦共 30 位。依其接受雞精意願分為控制組( $n=15$ )和雞精組( $n=15$ )。實驗期間，雞精組受試者每天分別於早、中，及晚餐後 30 分鐘內飲用一瓶雞精(70 mL/瓶)，每日 3 瓶。雞精組平均補充雞精為  $18 \pm 5$  天。控制組於研究進行期間，則限制其高蛋白飲食攝取。所有受試者均維持平日正常飲食。雞精組初乳中乳鐵蛋白、上皮生長因子、轉形生長因子- $\beta 2$  含量分別顯著較控制組高 34%、62%，及 196% ( $p < 0.05$ )。但雞精組初乳中總蛋白、酪蛋白，及乳白蛋白含量與控制組相較則無差異。綜合上述，補充雞精可提高哺乳婦女乳汁中乳鐵蛋白、上皮生長因子，及轉形生長因子- $\beta 2$  含量，可能對胎兒改善免疫功能和刺激生長發育有所助益。

## 母乳的營養與嬰兒副食品



趙振瑞 教授  
臺北醫學大學保健營養學系

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## Contents

- Nutrient requirements for infants
- Human milk
- Effects of nutritional factors on milk proteins
- Starting your baby on solid food
- Conclusion



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## Nutrient Requirements for Infants

- Energy requirement is determined by size, rate of growth, activity, and energy needed for metabolic activities
- Protein requirement:
  - 50% for growth in the first 2 mo
  - declines to 11% by 2-3 years of age
- Fat provides 40-50% calorie supplies (EFA)
- Carbohydrate: primarily lactose
- Water requirement: adequate human milk or formula

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## Dietary Reference Intakes

Age	Energy (kcal/kg)	Protein (g/kg)	Calcium (mg)
0 mo~	110-120	2.4	200
3 mo~	110-120	2.2	300
6 mo~	100	2.0	400
9 mo~	100	1.7	400

DOH, Taiwan, 2002

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## Water Requirements for Infants

Age	Body weight (kg)	Water (ml/d)	Water (ml/kg/d)
3 days	3.0	250-300	80-100
10 days	3.2	400-500	125-150
3 mo	5.4	750-850	140-160
6 mo	7.3	950-1,100	130-155
9 mo	8.6	1,100-1,250	125-145
12 mo	9.5	1,150-1,300	120-135

Barness, 1987

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## Lactogenesis

- colostrum  
6-12 h~2-3 d postpartum
- transitional milk  
1-2 wk postpartum
- mature milk  
> 3 wk postpartum

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## Human Milk Composition

- Immunoglobulins
- lactoferrin
- proline-rich polypeptide
- growth factors
- growth hormone
- leukocytes
- enzymes
- cytokines and lymphokines
- glycoproteins
- carbohydrate, fat, vitamins, and minerals

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## Human Milk Composition

Table 1 Chemical composition of human milk compared with milk from various species (values per 100 ml)

Constituents	Human milk	Cow milk	Buffalo milk
Protein (g)	1.2	3.3	3.8
Casein (g)	0.4	2.6	3.0
Lactalbumin (g)	0.3	0.4	0.4
Lactoglobulin (g)	0.2	0.2	0.2
Fat (g)	3.8	3.7	7.5
Lactose (g)	7.0	4.8	4.4
Calorie (Kcal)	71	69	100
Mineral matter (g)	0.21	0.72	0.80
Calcium (mg)	33	125	210
Phosphorus (mg)	15	96	130
Chlorine (mg)	43	108	112
Magnesium (mg)	4	12	15
Potassium (mg)	55	138	142
Sodium (mg)	15	58	65
Iron (mg)	0.15	0.10	0.20
Copper (mg)	0.04	0.03	0.02
Magnesium (mg)	0.7	2.0	-
Zinc (mg)	0.53	0.38	-
Iodine (mg)	0.007	0.021	0.004
Vitamin A (IU)	160	158	200
Vitamin D (IU)	1.4	2.0	-
Thiamine (mg)	0.017	0.04	0.05
Riboflavin (mg)	0.04	0.18	0.10
Nicotinic acid (mg)	0.17	0.08	0.28
Pantothenic acid (mg)	0.20	0.25	-
Vitamin B <sub>6</sub> (mg)	0.001	0.035	-
Folic acid (µg)	1.3	5.6	3.3
Biotin (µg)	0.4	2.0	-
Vitamin B <sub>12</sub> (µg)	0.03	0.50	0.30
Vitamin C (mg)	4.0	2.0	2.5

Source: Swaminathan (1998)

<http://www.emeraldinsight.com/fig/0170340402001.png>

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## Various Milk Compositions

	Protein (g/100 g)	Fat (g/100 g)	Carbohydrate (g/100 g)	Energy (kcal/100 g)
Human	1.1-1.2	3.8-4.5	6.8-7.0	66-73
Cow	3.1-3.9	3.5-4.9	4.6-5.1	62-80
Goat	2.9-3.4	3.5-4.1	4.6-4.7	62-69

Webb et al. 1974, Jensen 1995

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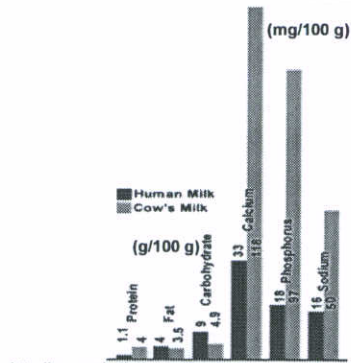
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## Various Milk Compositions



<http://www.mindfully.org/Food/Milk-Human-Cow-Comparison1986.gif> 10

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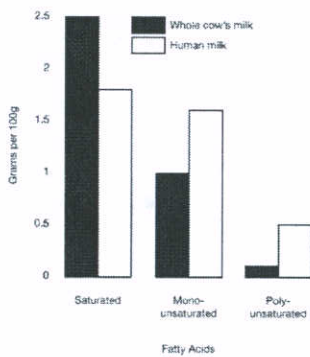
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## Various Milk Compositions in Fatty Acids



Food Science Association, 2002 11

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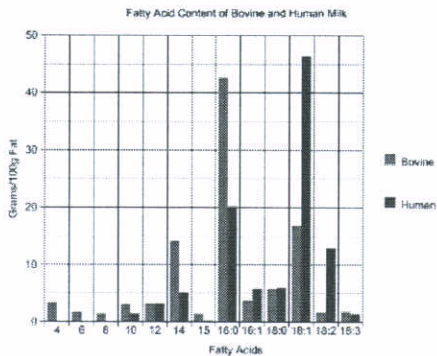
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## Various Milk Compositions in Fatty Acids



<http://www.raw-milk-facts.com/images/CowHumanFattyAcidGPH.jpg> 12

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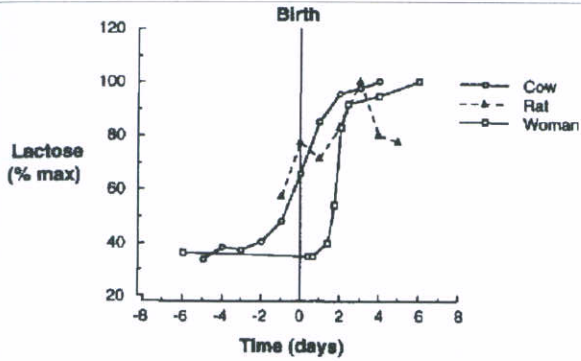
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### Changes in Milk Lactose



<http://www.unu.edu/unupress/food/8F174e/8F174E03.GIF>

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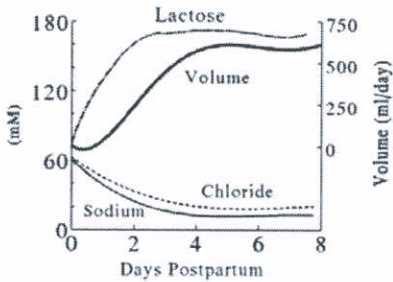
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### Changes in Human Milk Compositions



<http://mammary.nih.gov/Reviews/lactation/Neville001/index.html#lactogenesis>

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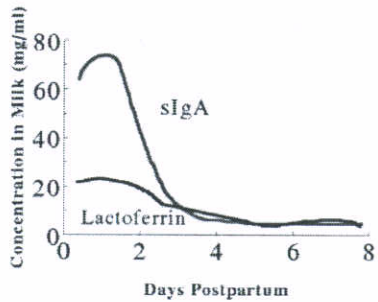
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### Changes in Human Milk Compositions



<http://mammary.nih.gov/Reviews/lactation/Neville001/index.html#lactogenesis>

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## Proteins in Human Milk

• whey/casein (100:0, 86:14, 76:24, 70:30, 65:35, 60:40, 50:50 vs cow 18:82)

• whey

- α-lactalbumin
- lactoferrin
- immunoglobulins
- lysozyme
- lactoperoxidase
- haptocorrin
- lactadherin
- bile salt-dependent lipase

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## Proteins in Human Milk

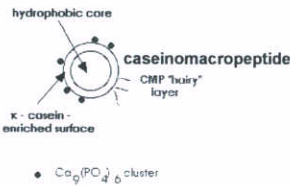
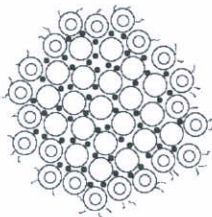
• casein (~30% of protein fraction)

α s1-, β-, κ-casein

cow: α-β-κ-casein = 50:36:13

Casein Micelle

Casein Submicelle



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## Hormones in Human Milk

Table 1. Some hormones and their concentrations found in human milk.\*

Hormone	Concentration
<b>Pituitary</b>	
Prolactin	20-90 ng/ml
Growth hormone	5-30 μU/ml
Thyroid-stimulating hormone	2.7-5.0 μU/ml
<b>Hypothalamus</b>	
Thyroid-releasing hormone	0.025-1.5 ng/ml
Luteinizing hormone-releasing hormone	Not available
Somatostatin	23-113 pg/ml
Gonadotropin-releasing hormone	0.1-4.0 ng/ml
Growth hormone-releasing hormone	23-430 pg/ml
<b>Thyroid</b>	
Thyroxine (T <sub>4</sub> )	0.3-12 ng/ml
Triiodothyronine (T <sub>3</sub> )	0.2-0.4 ng/ml
Reverse T <sub>3</sub>	0.008-0.15 ng/ml
<b>Parathyroid</b>	
Parathormone	15 pg/ml
Parathormone-related peptide	30-50 ng/ml
Calcitonin/calcitonin inhibiting protein	0-5 ng/ml
<b>Steroid</b>	
Estrogen	15-840 ng/ml
Progesterone	10-40 ng/ml
Adrenal steroids	0.2-32 ng/ml

\*Data from Hamosh (2001).  
<http://www.ehponline.org/members/2003/6023/table1.gif>

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## Growth Factors in Human Milk

- insulin-like growth factor (IGF)-I, -II
- epidermal growth factor (EGF)
- nerve growth factor (NGF)
- transforming growth factors (TGF- $\alpha$ , - $\beta$ 1, - $\beta$ 2)
- platelet-derived growth factor (PDGF)
- hepatocyte growth factor (HGF)
- colony-stimulating growth factor (CSGF)
- vascular endothelial growth factor (VEGF)

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## Factors in Human Milk

- antimicrobial factors
  - antibacterial factors
  - antiviral factors
  - antiparasite factors
- anti-inflammatory factors
- immunomodulators
  - nucleotides, cytokines
  - anti-idiotypic antibodies, lactoferrin

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## Antibacterial Factors in Human Milk

- secretory IgA, IgG, IgM, IgD
- analogues of epithelial cell receptors (oligosaccharides and sialylated oligosaccharides)
- *Bifidobacterium bifidum* growth factors (oligosaccharides, glycopeptides)
- other bifidobacteria growth factors ( $\alpha$ -lactoglobulin, lactoferrin, sialyllactose)
- carbohydrate

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## Antibacterial Factors in Human Milk

- cathelicidin
- casein,  $\kappa$ -casein, phosphorylated  $\beta$ -casein
- complement C1-C9 (mainly C3 and C4)
- $\alpha$ -,  $\beta$ -defensins
- factor binding proteins (zinc, vitamin B<sub>12</sub>, folate)
- ganglioside
- glycolipid Gb3
- glycoproteins
- $\alpha$ -lactalbumin

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## Antibacterial Factors in Human Milk

- lactoferrin
- lactoperoxidase
- lipids
- lysozyme
- milk cells (80% macrophages, 15% neutrophils, 0.3% B and 4% T lymphocytes)
- mucin
- phosphatidylethanolamine
- sialyllactose

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## Antibacterial Factors in Human Milk

- sialyloligosaccharides on sIgA
- CD14
- sulphatide (sulphogalactosylceramide)
- xanthine oxidase
- secretory leukocyte protease inhibitor
- heparin

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## Antiviral Factors in Human Milk

- secretory IgA, IgG, IgM
- *Bifidobacterium bifidum*
- chondroitin sulphate
- $\alpha$ -,  $\beta$ -defensins
- haemagglutinin inhibitors
- lactadherin (mucin-associated glycoprotein)
- histo-blood group carbohydrates
- lactoferrin

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## Antiviral Factors in Human Milk

- lipid (unsaturated fatty acids and monoglycerides)
- lysozyme
- $\alpha$ 2-macroglobulin
- milk cells
- neutrophil-derived  $\alpha$ -defensin-1
- ribonuclease
- secretory leukocyte protease inhibitor
- sialic acid-glycoproteins

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## Antiviral Factors in Human Milk

- soluble intracellular adhesion molecule 1 (sICAM-1)
- soluble vascular cell adhesion molecule 1 (sVCAM-1)
- sulphatide (sulphogalactosylceramide)
- vitamin A
- prostaglandins E1, E2, F2 $\alpha$
- gangliosides
- glycolipid Gb4
- heparin

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## Antiparasite Factors in Human Milk

- secretory IgA, IgG
- gangliosides
- lipid (free fatty acids and monoglycerides)
- lactoferrin
- macrophages

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## Anti-inflammatory Factors in Human Milk

- secretory IgA
- lactoferrin
- lysozyme
- $\kappa$ -casein
- antioxidants ( $\beta$ -carotene,  $\alpha$ -tocopherol, ascorbate, uric acid)
- EGF
- platelet activating factor-acetylhydrolase
- antiproteases ( $\alpha$ 1-antichymotrypsin,  $\alpha$ 2-trypsin)
- prostaglandins

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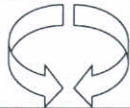
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## Nutritional Factors Affecting Milk Proteins



Weight loss  
2303 kcal  $\rightarrow$   $\downarrow$  538 kcal  
 $\downarrow$  4.8  $\pm$  1.2 kg  
In 10 weeks



$\times$  Milk quantity and quality

Dusdieker *et al.* 1994

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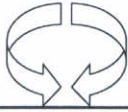
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## Nutritional Factors Affecting Milk Proteins

Moderately  
undernourished mother  
caloric supplement  
500 kcal/d vs 140 kcal/d



↑ secretory IgA × lactoferrin

Herias et al. 1993

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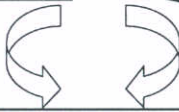
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## Nutritional Factors Affecting Milk Proteins

↓ meat, egg, dairy  
products, food  
prepared with oil

↑ rice,  
vegetables,  
beans, seaweed



↓ total protein at 2-5 mo postpartum

Yoneyama et al. 1994

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## Manufacture of Chicken Extract

高濃縮液、萃取雞油



採用最新科學的輸液方法，  
以超濃縮液14倍高濃的雞油，  
選擇純品質優良，且無任何防腐劑。

雞油去油

雞油經過最新科學方法處理，  
將油質及雜質完全去除，  
成為不含油質的雞油。  
也因此雞油的去油率，  
比一般市售的雞油高得多，  
且無任何防腐劑。



<http://www.brands.com.tw/cms.www/main.aspx?sid=415>

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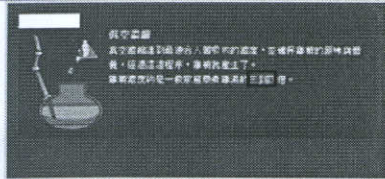
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## Manufacture of Chicken Extract



真空濃縮  
真空濃縮設備淨化、脫除水的鹼度，在條件嚴格的控制下將液體濃縮，使濃度達到標準，最終的產物上。

最終濃縮液是一個含有極高濃度的雞骨精華。

### Step 6.

脫水封蓋

將液體在抽真空狀態下，在真空密封的罐頭中，進行真空封蓋，及進行真空封蓋。



### Step 7.

脫水封蓋

將液體在真空狀態下，在真空密封的罐頭中，進行真空封蓋，及進行真空封蓋。

<http://www.brands.com.tw/cms.www/main.aspx?sid=415>

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## Chicken Extract Composition

Ingredient	Amount
weight/70 g (1 bottle)	
Protein	5.4 g
Purine	63 mg 中普林
Minerals	
Sodium	63 mg 低鈉
Potassium	155 mg 半根香蕉
Chloride	92 mg
Phosphorus	52 mg
Calcium	2.4 mg

普林：Japan Food Research Laboratories - 日本政府授權之實驗室  
蛋白質及礦物質：新竹食品工業研究所

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## Subject Inclusion Criteria

- non-vegetarians
- below 40 years old
- gravidity less than 3
- gestational age more than 37 weeks
- natural delivery of single birth
- free of any disease
- no pregnant complication
- without a history of smoking, alcohol, and drug abuse during the pregnancy

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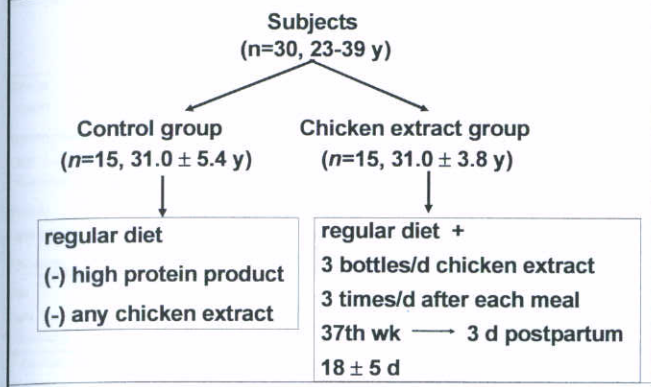
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## Experimental Designs




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## Human Milk Collection

- no breastfeeding 1 h before milk collection
- twice a day
- the interval at least 4 h
- electronic suction pump
- 15-min suction of each breast
- from 1 to 3 d postpartum
- 5-10 mL for protein analyses

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## Demographic and Clinical Characteristics

	Control	Chicken extract
Gestational weight gain, kg	16.4 ± 5.2	15.8 ± 4.9
Gestational age, weeks	38.9 ± 1.0	38.9 ± 0.9
Parity, n	1.4 ± 0.5	1.1 ± 0.4
Primiparous, n	9 (60.0%)	13 (86.7%)
Infant sex	9M, 6F	6M, 9F
Infant birth length, cm	51.3 ± 2.5	54.4 ± 2.3
Infant birth weight, g	3438 ± 205	3250 ± 397
Infant birth head circumference, cm	33.7 ± 0.9	33.4 ± 1.1

Chao *et al.* 2004 39

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## Daily Dietary Intake

	Control		Chicken extract			
	Pregnancy	Postpartum	Exclude	Include	Exclude	Include
			Pregnancy		Postpartum	
<b>Energy</b>						
kcal/d	1986 ± 293 <sup>1</sup>	2081 ± 373	2097 ± 449	2168 ± 449	1923 ± 206 <sup>#</sup>	1994 ± 206
<b>Carbohydrate</b>						
g/d	257 ± 63	257 ± 78	246 ± 77	246 ± 77	228 ± 52	228 ± 52
% energy	51.5 ± 8.1 <sup>1</sup>	49.0 ± 9.9	46.4 ± 9.0 <sup>1</sup>	44.8 ± 8.8	47.5 ± 9.9	45.8 ± 9.6
<b>Protein</b>						
g/d	82 ± 18 <sup>1</sup>	101 ± 18 <sup>2#</sup>	91 ± 20	109 ± 20 <sup>1</sup>	107 ± 30 <sup>#</sup>	125 ± 30 <sup>1</sup>
% energy	16.7 ± 3.4 <sup>1</sup>	20.1 ± 5.7 <sup>2#</sup>	17.7 ± 4.3	20.6 ± 4.8 <sup>1</sup>	22.4 ± 6.4 <sup>#</sup>	25.2 ± 6.3
<b>Fat</b>						
g/d	71 ± 16 <sup>1</sup>	73 ± 25 <sup>2</sup>	85 ± 24 <sup>*</sup>	85 ± 24	61 ± 17 <sup>##</sup>	61 ± 17
% energy	32.4 ± 6.8	31.3 ± 7.7	36.3 ± 7.0 <sup>1</sup>	35.0 ± 6.8	28.3 ± 7.1 <sup>#</sup>	27.3 ± 6.8

<sup>1</sup>vs control, <sup>2</sup>vs exclude, <sup>3</sup>vs include, <sup>#</sup>vs pregnancy (P<0.05) Chao *et al.* 2004 40

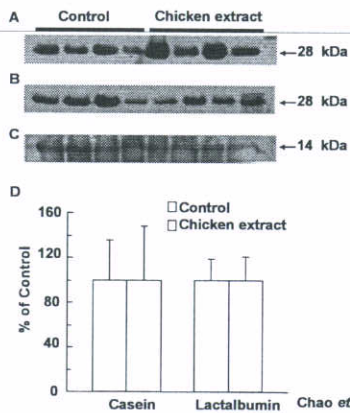
## Milk Protein Concentrations

	Control	Chicken extract
Total protein, g/L	64.9 ± 26.1	75.6 ± 47.5
Lactoferrin, g/L	7.3 ± 3.0	9.8 ± 3.5 <sup>*</sup> ↑ 34%
Epidermal growth factor, µg/L	146.8 ± 73.5	237.6 ± 144.6 <sup>*</sup> ↑ 62%
Transforming growth factor-β2, µg/L	7.8 ± 5.8	23.1 ± 17.4 <sup>*</sup> ↑ 196%
Secretory immunoglobulin A, g/L	4.1 ± 1.3	4.8 ± 1.5

<sup>\*</sup>vs control (P<0.05) Chao *et al.* 2004

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## Milk Casein and Lactalbumin



## Effects of Chicken Extract on Human Milk

Protein compositions of human milk can be altered by diet. Supplementation with chicken extract increases colostrum levels of lactoferrin, EGF, and TGF- $\beta$ 2, which are important for the growth and immune functions of the infants, in lactating women.



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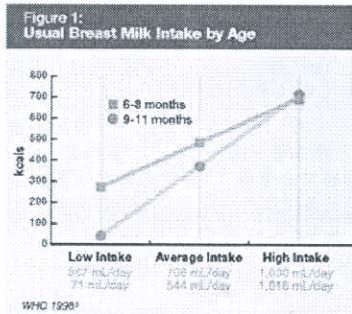
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## Breast Milk Intake for Infants



[http://media.gerber.com/nirt/cm2/upload/074FF5FE-6DA9-4E8F-A5C9-DF3A0DD4AB96/107\\_02-fig1.jpg](http://media.gerber.com/nirt/cm2/upload/074FF5FE-6DA9-4E8F-A5C9-DF3A0DD4AB96/107_02-fig1.jpg)

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## Solid Food for Infants

- WHO:

- 0-6 mo → exclusive breastfeeding
  - > 6 mo → solid foods

- Other organizations:

- 0-4 mo → breastfeeding or bottle-feeding  
not needed nutritionally, extrusion reflex
  - 4-6 mo → solid foods

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## Solid Food for Infants

- non-allergenic, easily digested, and rich in iron
- one new, "single-ingredient" food introduced per week
- gradually introduced by increasingly coarser textures



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## Solid Food for Infants

行政院衛生署針對4至6個月嬰兒每天飲食建議：

類別	五穀根莖類	蔬菜類	水果類	奶類
食物	米糊或麥糊	胡蘿蔔、菠菜、青江菜、小白菜、空心菜等蔬菜湯	橘子、柳丁、西瓜、蕃石榴、葡萄等自榨稀釋(1:1)果汁	母乳或嬰兒配方奶粉
份量	4湯匙	1~2茶匙	1~2茶匙	5次 170-200 cc/次

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## Solid Food for Infants

行政院衛生署針對7至9個月嬰兒每天飲食建議：

類別	五穀根莖類	蔬菜類	水果	奶類	蛋豆魚肉類
食物	1份：稀飯、麵條、麵線1/2碗、薄片土司麵包1片、饅頭1/3個、米粉、麥粉4湯匙	菜泥	自榨果汁或果泥	母乳或嬰兒配方奶粉	1份：蛋黃泥2個、豆腐1個四方塊或半盒豆漿240cc、魚泥、肉泥、肝泥1兩
份量	2.5-4份	1~2湯匙	1~2湯匙	4次 200-250 cc/次	1-1.5份

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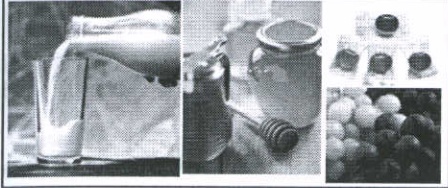
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## Solid Food for Caution



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## Conclusion

The American Academy of Pediatrics (AAP) recommends exclusive breastfeeding for a minimum of 6 mo and introduction of appropriate solid food from 6 mo to 1 yr.

Baby's  
First  
Food

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