Research Article **Open Access**

Enhancing nutritional care with egg white supplementation on serum albumin level for home-based bed-ridden elderly patients

Preeyabhorn Detarun[1], Vatcharee Srichamnanturakit[1], Sang-arun Isaramalai[2], Thaparat Rakpanusit[3]

[1]Center of Excellence in Functional Food and Gastronomy, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand; [2]Faculty of Nursing, Prince of Songkla University, Hat Yai Campus, Hat Yai, Songkhla 90110, Thailand; [3]Faculty of Nursing, Prince of Songkla University, Pattani Campus, Muang, Pattani 94000, Thailand

Corresponding authors: Preeyabhorn Detarun, Ph.D., Center of Excellence in Functional Food and Gastronomy, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand

Submission date: April 20th,2022; **Acceptance date**: May 23rd, 2022; **Publication date**: June 13th, 2022

Please cite this article as: Detarun P., Srichamnanturakit V., Isaramalai S., Rakpanusit T. Enhancing nutritional care with egg white supplementation on serum albumin level for home-based bed-ridden elderly patients. Functional Foods in Health and Disease. 2022; 12(6): 308-324. DOI: https://www.doi.org/10.31989/ffhd.v12i6.932

ABSTRACT

Background: Low serum albumin levels are one of the most common causes of morbidity and mortality in humans, particularly in older bed-ridden patients. Egg whites contains all the essential amino acids required, and it has many beneficial effects on the body. Supplementation with an egg white formula diet is expected to improve nutritional status and increase levels of serum albumin.

Objective: This research aimed to investigate the effects of the egg white formula diet (EWFD) supplement on serum albumin levels in bed-ridden elderly patients with nasogastric tube feeding at home.

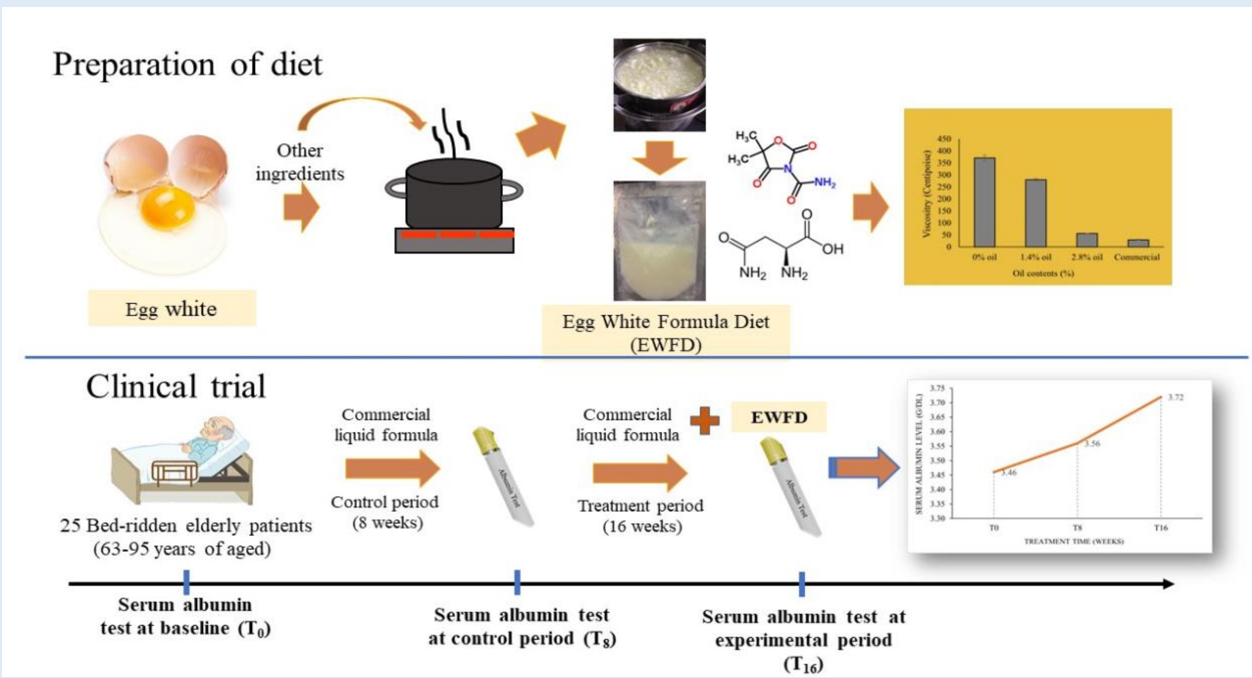
Methods: The experiment was designed as a quasi-experimental study with one single-sample group in 25 bed-ridden elderly patients who are > 60 years old, and were purposefully selected from a district in a Province in Southern Thailand. The experiment was divided into 2 periods (the control and experimental). The control period covered the first 8 weeks where the caregivers provided the usual care and administered the commercial liquid formula to the bed-ridden elderly subjects. The experimental period covered the following 8 weeks, where the caregivers provided the usual care, commercial liquid formula, and EWFD supplementation. Demographic data was collected using a data assessment form.

The effect of EWFD supplement on blood albumin levels in the bed-ridden elderly persons were measured at baseline (T_0), control (T_8), and experimental period (T_{16}).

Results: Serum albumin levels at T_0 in subjects who received the usual care program was an average of 3.46±0.35 g/dL. The average serum albumin level at the control period (T_8) was 3.56±0.44 g/dL, while after the experiment (feeding including egg white for 8 weeks) was 3.72±0.45 g/dL. The serum albumin levels significantly increased compared to the control and experimental periods (p= 0.042).

Conclusion: Enhancing nutritional care through egg white supplementation improved the serum albumin levels in bed-ridden elderly patients at home. It is therefore recommended that the longitudinal study design should be implemented to monitor and maintain the serum albumin, which consequently promotes the patients' nutritional status.

Keywords: nutritional status; bed-ridden elderly; nasogastric tube feeding; bed-ridden; egg white; serum albumin; muscle mass



INTRODUCTION

Nutritional status is an important factor affecting the quality of life of the elderly. As it affects the duration of treatment and the cost of treatment. Nutrition status may also affect other issues such as economic and social problems [1]. Malnutrition is considered an important issue that threatens both the health and lives of elderly people [2]. It is more common in elderly people and tends to be higher in bed-ridden elderly patients who need to be assisted with all daily activities [3]. Malnutrition problems in elderly people are usually caused by inadequate food intake according to the requirement, chewing and swallowing issues, poor quality food, and poor absorption. This problem shows the importance and the need for additional nutritional care systems for bed-aged seniors to prevent the likelihood of serious illness. These problems can be solved by preventing nutritional deficiencies [4].

Malnutrition in bed-ridden elderly people results in more deterioration of various systems, including disorders of the various sensory systems, lack of tissue tightness, thinner bones, increased muscle breakdown, reduced muscle volume, and lean muscle mass. A decrease in muscle mass by 10 percent, consequently, decreases the immune system, thereby they are to more suspectable to infections and even death [5]. In addition, the lack of body movement for a long time may lead to reduced protein synthesis [6]. The effects of malnutrition also may lead to muscle protein breakdown, resulting in the deterioration of illness. The promotion of protein supplements in bed-ridden elderly people is therefore very important to repair the body and compensate for metabolic disorders [7].

Protein is an important nutrient for elderly people that helps to restore bone mass, maintain energy in the body, enables the cardiovascular system to work well, helps the healing of wounds, and improves the function of the body, as well as increases the quality of life [8]. Elderly people with chronic diseases, living with malnutrition, or at risk of malnutrition need protein nearly 1.2-1.5 g / kg/day [6]. The problem of malnutrition often comes from a lack of protein with a negative nitrogen balance, resulting in the loss of muscle mass and decreased albumin protein levels in the blood. The albumin protein is a biomarker that indicates the severity of the disease. It is a predictor of complications from the disease, disability, and mortality in elderly people [9].

Current studies have found that the decline in muscle mass in elderly people is a physiological change that could be avoided. An experiment in the elderly people who consumed more than 1.1 g of protein/kg of body weight/day found that the loss of muscle mass was less than those observed in elderly people who consumed less than 0.7-0.9 g of protein /kg body weight/day [10]. Good nutrition, especially with sufficient protein intake, helps to limit muscle mass degeneration, strength, and age-related functions [6]. In addition, the requirements for elderly people include a high-quality protein to help slow down the loss of muscle mass.

Eggs are an inexpensive, widely available, and easily digestible source of high-quality protein. Egg whites, which contains albumin as the main ingredient are the most abundant protein in the plasma. It is also responsible for maintaining the osmotic pressure of the blood, transporting various substances in the bloodstream. It also plays a role in reducing acidity in the blood [11]. Egg whites contain all the essential amino acids required by the body [12]. It has many beneficial effects on the body such as stimulating the growth of cells and the immune system [11, 13]. Therefore, egg white is a protein that is suitable as a dietary supplement for people who need a high amount of protein, such as bed-ridden people. Moreover, egg white protein contains no cholesterol, it is inexpensive and conveniently accessible. Accordingly, albumin proteins from egg whites are important in promoting the nutritional status of bed-ridden elderly people.

Promoting nutritional status by tube feeding can improve the nutritional status of bed-ridden patients [14]. Tube feeding has advantages for patients who stay in bed for treatments at home. Although it is not as sterile as intravenous administration, it contains natural foods with a variety of nutrients. It can be readily available by adding into the liquid formula diet to get nutritious food, which is suitable for elderly patients who stay in bed for a long time [15]. Therefore, this research aimed to compare the mean levels of serum albumin in bed-ridden elderly patients before and after egg white as a supplement.

MATERIALS AND METHODS

Preparation of Egg White Formula Diet (EWFD): Egg white formula diet (EWFD) for the nasal feeding tube was developed. Ingredients for EWFD were purchased from a local convenience store and consisted of pasteurized chicken egg white, soybean oil, hot water, and vanilla flavor. Three formulas with different amounts of soybean oil, 2.8 %, 1.4 %, and 0 % of the oil were prepared. The pasteurized chicken egg whites were cooked at 60°C for 30 min in the jackets boiling water pot. Then, it was homogenized using a sterilized glass blender (MX-GX1561, Panasonic, Japan), soybean oil, hot water, and vanilla flavor were added. The product was passed through a sieve before packing it into the sterilized bags. Finally, the packed product was pasteurized in hot water at 70^{0}C for 15 seconds, followed by rapid cooling to about 4^{0}C. Preparation of the diet for the feeding tube was done in a sterile clean room to prevent contamination with pathogens or bacteria. The final product was stored in the refrigerator at 4°C. The proximate and physical properties of the products were determined. Thereafter, EWFD was served to the bed-ridden patients at home for testing the effects of EWFD on albumin levels in the blood.

The physical properties of EWFD: Viscosity was measured by Brookfield Digital viscometer (Model LV2) method at 100 rpm, spindle No. 63, at temperature 36-38^{0}C. The results were typically expressed in centipoise (cps). Color was determined using Hunter lab colorimeter (Color Flex, Hunter Lab Inc., Reston, VA, USA). Viscosity and color parameters of EWFD were compared with the commercial product (Blendera-MF) from Thai Otsuka Pharmaceutical Co., Ltd.

Determination of Shelf-life parameters of EWFD: pH was determined using a PH meter, total acid was determined according to AOAC [16]. microbial The testing included total viable count, yeast and mold, Coliform, *Escherichia coli,* and *Salmonella* spp., and they were studied throughout the shelf-life period for 14 days in the refrigerator according to Food Safety Authority of Ireland [17].

Clinical: Study population: The subjects were purposively selected from tube-feeding bed-ridden elderly patients staying at home in a district in one of the Provinces in Southern Thailand. The general information of these subjects is presented in Table 1. Main inclusion criteria: subjects had Barthel ADL Index in the range of 0-4 points according to Wade and Collin [18], had tube feeding, and no pressure sores. Informed consent was made for every subject. The bed-ridden patients with a pressure sore, acute illness or severe symptoms, restriction of protein intake by the doctor's order, specific nutritional care to the symptoms of the disease, such as liver disease, various cancers, kidney disease, and heart disease were excluded from the study. Furthermore, elderly bed-ridden patients who showed diarrhea or were unavailable to participate throughout the study were also excluded. This study received full ethical approval from the Human Ethics Committee of the Faculty of Nursing, Prince of Songkla University.

Experimental designs and intervention: This quasi-experimental study was conducted in one group with twenty-five bed-ridden elderly patients (twelve males and thirteen females; the age range was between 63 and 95), measured in a one-group time-series design.

Of 25 patients participating in this study, they were tube-fed via the nose. The experimental schedule involved daily usual care with a blended diet administration for 8 weeks, followed by daily administration of blended diet supplemented with EWFD, 3 times per day (at 10.00 am, 02.00 pm, and 07.00 pm) for 8 weeks. Each subject consumed approximately 1200 kcal per day in total energy from the blended diet and EWFD supplement. Depending on albumin levels at baseline, the daily extra protein in the EWFD was established at 20-70 g/d.

A blood sample of approximately 3 mL was collected from the vein in the morning by the nurse in charge of the project at baseline (T_0), control period (T_8), the experimental period (T_{16}), and the blood collection tube. This was stored in a cool bag before sending it to certified laboratories for testing serum albumin protein. This study evaluated serum albumin levels in bed-ridden elderly patients by evaluating 3 times, namely the 1st (T_0) before the control period in the first week, and the second time (T_8) after the control period in the 8th week. In which it was used as a result of the evaluation before the trial period and the 3rd time (T_{16}) after the 16th week trial.

General information of the elderly bed-ridden subjects

The subjects used in the study were 25 bed-ridden elderly persons. Most of them were female (52% of female and 48% male, respectively), aged between 63 and 95 years, with an average age of 77.36 years (SD = 0.84). Most of the subjects were completed primary education (60%). Forty-four percent of the subjects were married, relied on their own houses (48 %), or lived at home with their children/grandchildren (40 %) (Table 1)

Table 1. General information of bed-ridden elderly people (N = 25)

General information		No	Percentage
Gender	Male	12	48.0
	Female	13	52.0
Age (years) **Mean = 77.36, SD = 0.84, Min = 63, Max = 95**	60-69	7	28.0
	70-79	9	36.0
	80+	9	36.0
Educational status	Uneducated	3	12.0
	Primary school	15	60.0
	Secondary school	4	16.0
	Graduated School	3	12.0
Marital status	Single	2	8.0
	Couples	11	44.0
	Widow	10	40.0
	Divorce	2	8.0
Residence	Own home	12	48.0
	Children/grandchild's home	10	40.0
	Sister's / relative's home	1	4.0
	House for rent	2	8.0

Health information of the bed-ridden elderly subjects

The results of this study showed that the health issues of the bed-ridden subjects were majorly from stroke (72%), with an illness duration of more than 1 year (68%). Most of the liquid food used was instant food formula (72%), followed by blended food (24%). The amount of water given at most meals was 51-100 mL (44%), followed by 50 mL (32%). The bed-ridden subjects had no history of both food allergies and gastrointestinal symptoms. All bed-ridden elderly subjects had a good history of tube feeding. The Barthel ADL index scoring was equal to 0 (72 %), followed by a score of 1 (16%) as shown in Table 2.

Table 2. Number and percentage of health data of bed-ridden elderly subjects (N = 25)

Health information		No	Percentage
Disease	Stroke	18	72.0
	Diabetes mellitus	9	36.0
	Hypertension	17	68.0
	Dyslipidemia	2	8.0
	Parkinson's disease	3	12.0
	Alzheimer's disease	5	20.0
	Heart disease	1	4.0
Disease	Chronic obstructive pulmonary disease	2	8.0
	Accident	2	8.0
	Psoriasis	1	4.0
	Lung atelectasis	1	4.0
	Thoracic Aortic Aneurysm	1	4.0
Illness duration	<6 month	4	16.0
	6 -12 month	4	16.0
	>1-3 years	7	28.0
	>3-5 years	6	24.0
	>5-10 years	3	12.0
	>10 years	1	4.0
Liquid formula diet			
	Blenderized Diet	6	24.0
	Instant food formula	18	72.0
	Blenderized Diet + Instant food formula	1	4.0
The volume of water given in each meal (ml)			
	50	8	32.0
	51-100	11	44.0
	101-200	5	20.0
	>200	1	4.0
Food allergy history			
	No	23	92.0
	Yes	2	8.0
History of food intake via nasogastric tube			
	Good intake, no food leftover	25	100.0
The ability to carry out daily life by Barthel ADL index (score)			
	0	18	72.0
	1	4	16.0
	3	1	4.0
	4	2	8.0

Statistical analysis: The comparative analysis of the mean serum albumin levels in elderly persons consisted of different periods using the One-way repeated measure ANOVA and analyzing the individual differences over time by the Bonferroni method. A probability (*p*) of < 0.05 was considered as significant.

RESULTS

Proximate composition of EWFD: The nutritional composition of the chicken egg white and the formulated EWFD for bed-ridden patients are presented in Table 3. The chemical composition of the chicken egg white was the highest amount of moisture (78.40 ± 2.40 g/100 g), followed by protein (12.51 ± 1.30 g/100g) and carbohydrate content (7.89 ± 2.53 g/100 g). The energy content of a chicken egg white showed a value of 84.3 ± 5.16 kcal.

For the formulated EWFD, it is noticeable that EWFD shared a similar pattern in all proximate analyses with chicken egg whites. Formulated EWFD at different percentages of soybean oil (0, 1.4, and 2.8) were the highest in moisture content range from 90.96 ± 0.05 to 92.66 ± 0.51 g/100g, followed by 5.54±0.06 to 5.87±0.14 g/100g of protein, and 0.81 ± 0.03 to 2.24 ± 0.05 g/100g of total carbohydrate. Energy values were shown in the range of 26.76 ± 0.21 - 37.67 ± 0.39 kcal/100 g of the EWFD sample.

Table 3. Proximate composition of chicken egg white and final product per 100 g edible portion.

Parameters (g/100 g)	Chicken egg white	EWFD (0% oil)	EWFD (1.4% oil)	EWFD (2.8% oil)
Ash (g)	0.90±0.05	0.35±0.01^{b}	0.41±0.01^{a}	0.41±0.01^{a}
Moisture (g)	78.40±2.40	92.66±0.51^{a}	92.44±0.46^{a}	90.96±0.05^{b}
Protein (g)	12.51±1.30	5.83±0.04^{a}	5.54±0.06^{b}	5.87±0.14^{a}
Crude fat (g)	0.30±0.01	0.00^{c}	0.11±0.01^{b}	0.59±0.01^{a}
Total Carbohydrate (g)	7.89±2.53	0.81±0.03^{c}	1.70±0.09^{b}	2.24±0.05^{a}
Energy (Kcal)	84.3±5.16	26.76±0.21^{c}	29.63±0.19^{b}	37.67±0.39^{a}

EWFD; egg white formula diet. Values are shown as means ± S.D. Values with different superscript letters in the same row indicate significant differences at P <0.05.

Physical properties of EWFD

Viscosity parameter of EWFD and commercial product is shown in Figure 1. EWFD has a viscosity in the range of 56.10 ± 0.95 to 370.50 ± 11.76 cps. The viscosity of the EWFD for bed-ridden patients was inversely proportional to the amount of soybean oil added. Viscosity significantly decreased in a linear fashion from 370.50 ± 11.76 cps at 0% soybean oil to 280.20 ± 4.61 cps with 1.4% added soybean oil, and to 56.10 ± 0.95 cps with 2.8% added soybean oil. With each 1.4% of added soybean oil, viscosity was reduced by 24% and 80% of soybean added respectively. While the commercial formula, Blender-MF, showed significantly lowest viscosity when comparing with developed product (29.60 ± 1.82 cps).

The color value of the EWFD and commercial products are presented in Table 4. All 3 concentrations of soybean oil in EWFD for bed-ridden patients had red values, but the commercial formulas had green values and all four formulas had yellow values. While the trade formula is the most valuable. The formula of the product was significantly reduced as the oil content increased as shown in Table 4. The developed formula had more brightness (L*) than the commercial formula. It had a green-yellow tone, while the commercial formula had a red-yellow tone (Table 4).

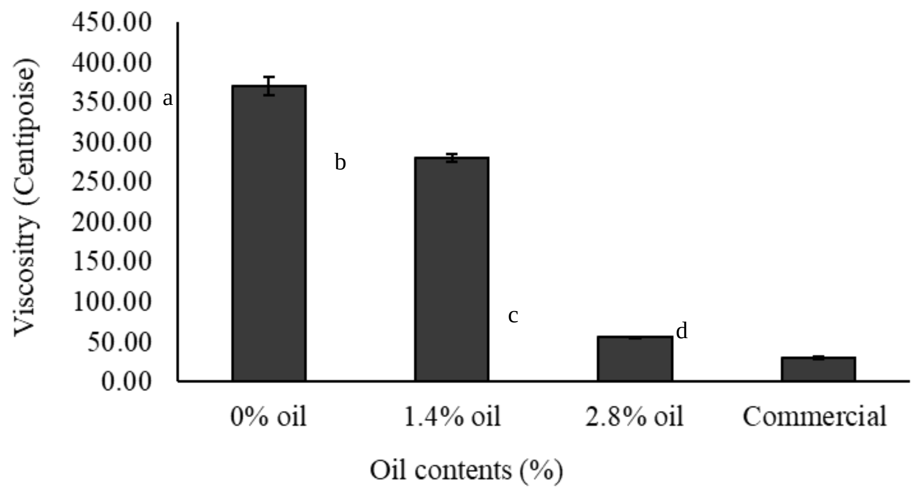


Figure 1. Viscosity of EWFD according to oil content. The commercial formula is Blendera-MF.

Table 4. Color values of EWFD products for bed-ridden elderly patients

Parameters	EWFD (0% oil)	EWFD (1.4% oil)	EWFD (2.8% oil)	Commercial product*
color				
L*	90.56±0.03^{c}	91.85±0.02^{a}	90.78 ± 0.01^{b}	79.93 ± 0.02^{d}
a*	-2.34±0.14^{c}	-1.84±0.03^{b}	-2.39 ± 0.04^{c}	1.78 ± 0.01^{a}
b*	13.97±0.16^{b}	12.56±0.07^{c}	11.09 ± 0.04^{d}	19.73 ± 0.05^{a}

Values are shown as means ± S.D. Values with different superscript letters in the same row indicate significant difference at P <0.05.

Blendera-MF. When L indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate.

Shelf-life of EWFD: The EWFD developed for bed-ridden patients was stored at 4°C for 14 days, with sampling days at 0, 3, 7, and 14 to monitor the total viable count, yeast and mold, coliforms, *Escherichia coli,* and *Salmonella* spp. According to the FDA guidelines, food products are unacceptable for consumption with the following conditions: 1) aerobic counts exceed 10^4 CFU/g in a single sample; 2) 10^3 CFU/g in 3 or more samples; 3) coliform count >3 organisms/g; and 4) positive for *L. monocytogenes* or *Salmonella* species[19]. From the study, it was found that total viable count, yeast and mold, coliforms, *Escherichia coli*, and *Salmonella* spp. did not exceed the standard criteria throughout the study as shown in Table 5.

The acid (pH) value of the products was within the range of 9.03 ± 0.01 - 9.25 ± 0.00 for 14 days storage time at 4°C (Table 6). As the storage time increases, the acid-base of the product tends to decrease. Normally, the pH value of a fresh egg white is about 7.6 (alkaline properties), and the pH value of the products increased to 9.2 after a long time of storage [20].

Total acid contents revealed that the product developed, when stored at 4°C for 14 days had no organic acid contents (Malic acid, Citric acid, and Tartaric acid), an indicator of food degradation. Therefore, the product developed is safe in terms of both microbial contamination and acidity when stored at 4°C for 14 days as shown in Table 6.

Table 5. Shelf-life of EWFD for bed-ridden elderly patients.

Storage time at 4⁰C	Parameters	Results		
		EWFD (0% oil)	**EWFD (1.4% oil)**	**EWFD (2.8% oil)**
Day 0	Total viable count	25 CFU/g	40 CFU/g	< 10 CFU/g
	Yeast and Mold count	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g
	Coliforms	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Escherichia coli	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Salmonella spp.	Negative	Negative	Negative
Day 3	Total viable count	30 CFU/g	35 CFU/g	< 10 CFU/g
	Yeast and Mold count	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g
	Coliforms	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Escherichia coli	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Salmonella spp.	Negative	Negative	Negative
Day 7	Total viable count	30 CFU/g	30 CFU/g	< 10 CFU/g
	Yeast and Mold count	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g
	Coliforms	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Escherichia coli	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Salmonella spp.	Negative	Negative	Negative
Day 14	Total viable count	35 CFU/g	40 CFU/g	< 10 CFU/g
	Yeast and Mold count	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g
	Coliforms	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Escherichia coli	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
	Salmonella spp.	Negative	Negative	Negative

CFU, colony-forming unit. MPN, most probable number

Table 6. pH and free acid contents in the products.

Storage time at 4⁰C	Parameter	Results		
		EWFD (0% oil)	**EWFD (1.4% oil)**	**EWFD (2.8% oil)**
Day 0	pH	9.25±0.00	9.03±0.01	9.06±0.01
	Malic acid	ND	ND	ND
	Citric acid	ND	ND	ND
	Tartaric acid	ND	ND	ND
Day 3	pH	9.09±0.01	9.05±0.01	9.09±0.01
	Malic acid	ND	ND	ND
	Citric acid	ND	ND	ND
	Tartaric acid	ND	ND	ND
Day 7	pH	9.11±0.01	9.07±0.01	9.12±0.01
	Malic acid	ND	ND	ND
	Citric acid	ND	ND	ND
	Tartaric acid	ND	ND	ND
Day 14	pH	9.04±0.01	8.91±0.01	9.02±0.01
	Malic acid	ND	ND	ND
	Citric acid	ND	ND	ND
	Tartaric acid	ND	ND	ND

ND: Not detected

Effect of EWFD on serum albumin level in elderly bed-ridden subjects serum albumin levels in the control and experimental periods: It was observed that the mean serum albumin levels in the bed-ridden elderly subjects after the control period increased. Serum albumin levels during the control period in subjects who received the usual care program was an average of 3.46 g/dL (SD = 0.35) and after the control period was 3.56 g/dL (SD = 0.44). After the experiment, the mean serum albumin level of subjects increased when compared to that observed at the beginning of the experiment. The average serum albumin level before the experiment was 3.56 g/dL (SD = 0.44), while after the experiment (feeding including egg white for 8 weeks) was 3.72 g/dL (SD = 0.45) (Table 7).

Table 7. Serum albumin levels before and after participating in the intervention (N=25)

Collection time	Treatments	Serum albumin level (g/dL)		
		Min-Max	Mean	SD
1^{st}	T_0: Before treatment	2.66-4.13	3.46	0.35
2^{nd}	T_8: 8 weeks after administration	2.75-4.32	3.56	0.44
3^{rd}	T_{16}: 16 weeks after administration	2.75-4.49	3.72	0.45

Comparing the mean of serum albumin levels between control and experimental periods in bed-ridden elderly subjects: There is at least one-pair difference ($F (2, 48) = 7.35$, $p < 0.05$) of mean serum albumin levels in bed-ridden elderly subjects (as shown in Table 8). Figure 2 shows that the average serum albumin level increased at each stage, while the mean albumin serum level at the 3^{rd} pair (before the control - after the experimental period) were significantly different ($p < 0.05$). However, pair 1 (before - after the control) and pair 2 (before - after the experiment) were not significantly different ($p > 0.05$) as shown in Table 8.

Table 8. Comparison of serum albumin levels in bed-ridden elderly subjects before and after participating in the control and experimental period by using statistical analysis of One-way repeated measure ANOVA measurement.

Source of variance	SS	df	MS	F^a	P-value
Within the group					
Time period	0.90	2	0.45	7.35	0.13
Discrepancy	2.95	48	0.06		

SS= Sum of Squares; df= degree of freedom; MS= Mean square

[a] Sphericity Assumed

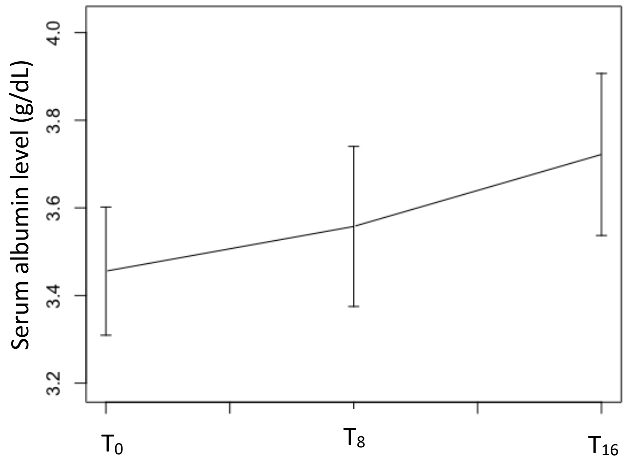


Figure 2. The difference of mean serum albumin levels in the elderly bed-ridden subjects during the first week (T_0), after the 8th week (T_8), and after the 16th week (T_{16}).

Table 9. Comparison of pairs' differences in mean serum albumin level in bed-ridden elderly subjects in the control and experimental period, using *One-way repeated measure ANOVA*

Pairs' differences of serum albumin level	Mean Difference	Std. Error	95% confidence interval for Difference		*F*-value
			Lower Bound	Upper Bound	
Pair 1: before-after control period (T_0-T_8)	-0.10	0.05	-0.24	0.04	7.35[b]
Pair2: before-after experiment (T_8-T_{16})	-0.16	0.08	-0.36	0.03	
Pair 3: before control-after experiment (T_0-T_{16})	-0.27*	0.08	-0.47	-0.07	

* p <0.05

[a]Adjustment for multiple comparisons: Bonferroni; [b]Test of Within-Subjects Effects: Sphericity Assumed; *df* 2, 48

Comparison of the pairs' differences in mean serum albumin level in bed-ridden elderly subjects is presented for the control and experimental period. The results represent pair 1; before the control period (T_0) and after the control period (T_8), pair 2; before the experimental period (T_8) and after the experimental period (T_{16}), for the subjects who participated in the dietary intervention of egg white as a dietary supplement. There was no significant difference in the serum albumin levels. However, the result showed that in pair 3 (before the control period (T_0) and after the experiment (T_{16})), the mean serum albumin levels significantly increased (p < 05). This reveals that the application of EWFD as a dietary supplement caused the serum albumin concentration to increase by 0.16 (g/dL). However, when comparing serum albumin levels before the control (T_0) and post-test (T_{16}) levels, it was found that the serum albumin levels increased to 0.27 g/dL which could be discussed as follows.

DISCUSSION

Proximate composition of EWFD: The main objective of this product development was to increase protein and energy intake aside from the main meal of the bed-ridden patients. Adequate protein and energy intake helped to reduce the risk of catabolism of muscle, death risk factor, maintains the muscle composition, and consequently leads to reduced death incidence in elderly people [21].

Chicken egg white is considered a good source of protein because it is composed of all the essential amino acids. Stadelman and Cotterill [22] reported that egg white contains about 11-12% of protein. These proteins such as ovalbumin (54%), Ovo transferrin (12%), ovomucoid (11%), lysozyme (3.5%), and ovomucin (3.5%) are considered as the main proteins in egg white. Ovalbumin, which is the major egg white protein, has well-balanced amino acid composition, and thus can be used as an excellent protein source in many food items for all age groups especially in elderly and bed-ridden patients [23].

Bed-ridden patients are unable to have their diets directly by eating but are fed through a tube. Therefore, it is necessary for the chicken egg white to be modified into the liquid form. In this study, we remodeled egg white into a liquid formula diet by adding water and oil to enhance its suitability for tube feeding. There are some limitations of formula diet for the bed-ridden patient in this study. For example, if patients had phlegm, then oily foods were strictly avoided. Thus, EWFD with three different oil content were produced.

Physical properties of EWFD: Viscosity of blenderized tube feeding diets varies significantly between different commercial, hospital and home prepared blends. Sullivan et al [24] reported the range of viscosity of hospital-prepared blenderized diets from 20 to >45,000 cps. Hron and Rosen [25] reported that there were significant variations in viscosity between commercial blends with value ranging from extremely to mildly thick by Syringe Flow Test. The highest cps value was 13,847 and the lowest 330 and 438 cps. In this study, EWFD viscous was ranging from 56.10 ± 0.95 to 370.50 ± 11.76 cps. Increasing the oil contents (0, 1.4, and 2.8%) in EWFD resulted in a decrease in viscosity of EWFD, while the commercial, Blendera-MF had 29.60 ± 1.82 cps. Blenderlized tube feeds administered via enteral tube are popular alternatives to the conventional enteral formula in both pediatric and elderly populations. Previous studies showed a beneficial effect of viscous feeding by decreasing gastroesophageal reflux disease and reducing daily fevers in neurologically compromised adults fed via an enteral tube [25]. One of the proposed mechanisms could be that thick feeds may shift the food bolus to the distal stomach and away from the cardia and lower esophageal sphincter, thereby reducing bolus movement into the esophagus [25].

Shelf-life of EWFD: Contamination of Blenderized Tube Feeding (BTF) with micro-organisms can occur at any step throughout the preparation, production, storage, or administration process. At either end of the age spectrum or with a change in gastrointestinal barrier function, this can present a major risk to the patient, particularly if they are immune deficient [26]. Therefore, many healthcare facilities have banned BTF due to concerns about microbial overload and potential infection in immune-compromised patients. Healthcare facilities recommend a commercial formula for many reasons. For instance, commercial formulas have a sterile preparation process, have a known nutrient composition, and are less labor-intensive to administer compared to BTF [27]. However, some physicians believed BTF to be of superior quality to a commercial formula, confirming that no manufactured product is superior to natural foods. Moreover, interest in and use of BTF have recently increased by patients and caregivers. Some caregivers and healthcare providers reported that BTF supports growth in children, sustains weight in adults, alleviates tube feeding intolerance (retching, vomiting, gastric pain, constipation), improves oral intake, and is less expensive than commercial formulas.

Blenderized tube feeding (BTF) liquid form is considered an ideal growth medium for potentially pathogenic micro-organisms. However, Johnson et al [28] studied three tube-feeding formulas; commercial formula (CF), a BTF- made using baby food (BTF-BF), and a BTF prepared from blending whole food (BTF-WF). These formulas were prepared in a U.S. hospital and delivered *in vitro* to an uninhabited patient room. Samples were collected at zero hours, 2 hours, and 4 hours and evaluated for growth of aerobic microorganisms, *Staphylococus aureus*, coliforms, and *Escherichia coli*. They found that no *S. aureus* or coliform/*E. coli* were detected at any time following preparation, and the total bacterial count was well below acceptable limits. All the three feeding formulas at zero hour, 2 hours, and 4 hours for each of the 3 sampling hours were acceptable for human consumption [28]. Klek et al [29] reported improved outcomes in home enteral nutrition patients when managed by healthcare providers regardless of BTF or CF use. They demonstrated that BTF prepared according to recommended methods can have equivalent and acceptable bacterial loads with CF, even when the time/temperature limits of the tube feeding exceeded healthcare facility recommendations by 2 hours. Baniardalan et al [30] reported that potential sources of contamination may include original food items, food preparation techniques, equipment/utensils, kitchen hygiene, time/temperature violations in preparation, delivery, and storage of products. Therefore, we concluded that appropriate BTF recipe selection and adherence to safe food handling can provide a safe feeding substrate equivalent to commercial formulas.

Effect of EWFD on serum albumin level in elderly bed-ridden subjects: The aim of this study was to determine the effect of EWFD supplementation on albumin levels in home-based bed-ridden elderly patients. Our findings showed that daily supplementation of EWFD resulted in an increase in the albumin level. These observations suggested that an increase in the protein intakes during the 8-week periods were related to increased albumin levels.

The nutritional value of egg white protein is derived from protein digestion via several steps. The mechanism of ovalbumin protein hydrolysis by using different gastrointestinal enzymes has been discovered long time ago. Starting in the stomach by pepsin enzyme, zymogen precursor activates pepsin to digest protein at acidic pH. Then it releases polypeptides, oligopeptides, and free amino acids. Enteropeptidases on duodenal enterocytes activate the protease enzymes, i.e., chymotrypsin, and trypsin. Hence, polypeptides are hydrolyzed by pepsin enzyme at the peptide bond on carboxyl side of arginine and lysine, whereas the bond on carbonyl moiety of tyrosine, tryptophan and phenylalanine are also hydrolyzed by chymotrypsin. Both chymotrypsin and trypsin can

also hydrolyze ovalbumin upon the specific cleavage sites to produce an abundance of amino acids. Finally, the transportation of free amino acids, dipeptides, and tripeptides is carried out by the carrier-transporters through the brush border membrane [31].

Although egg white is digested into ovalbumin and then absorbed into the blood, it is not the same as albumin in the blood. The albumin in the blood is a simple protein made by the liver. A typical reference range for normal albumin levels is 3.5 to 5.4 g/dL (34 to 54 g/L) [32]. It plays many important roles including maintenance of appropriate osmotic pressure, binding, and transport of various substances like hormones, drugs, etc. in blood, and the neutralization of free radicals. Both acute and chronic disorders lead to hypoalbuminemia, edema, and many other disorders [32].

Furthermore, the protein egg white might also be the high protein diet for hemodialysis (HD) patients accompanied by the need for lower phosphorus. The research work of Kalantar-Zadeh et al [33] reported that the high protein content in an egg white-based diet has shown increased serum albumin concentrations in HD patients. The serum albumin of the intervention group significantly decreases protein malnutrition and enables it to decrease in high mortality for HD patients after 3 months of treatment of an egg white-based diet. Moreover, not only organic phosphorus but also inorganic phosphorus in the serum was reduced without inducing protein malnutrition. The total weekly phosphorus intake in HD patients should be on an average of 2.4 - 3.6 g/weeks [34]. It is remarkable that the high protein of egg white-based diet and the association with low phosphorus levels has relevant practical implications. Therefore, an egg white diet may be used in the treatment of hyperphosphatemia in HD patients associated with bed-ridden elderly persons. Normally, researchers recommended that the protein requirement in bed-ridden patients ranges between 1.0 - 1.2 g per Kg of body weight/day [35]. From this study, patients were fed with blended diet four serving per day using ratio 1:1 formula (250 ml: 250 kcal) with protein and energy intake around 40 g and 1000 kcal, respectively. Moreover, when bed-ridden patients were fed with both blended diet and EWFD supplement (3 times per day with 150 ml per 1 time), they received approximately 60 - 65 g of protein which met the requirement.

From the data analysis, it was observed that at the end of the experiment, the serum albumin levels had a statistically significant increase. It seems that providing egg white as a food supplement could increase the level of serum albumin. Our finding shows that EWFD could potentially develop into a functional food product (FFP) in the future. The detailed steps to develop FFPs have been described by Martirosyan et al [36]. However, the duration of the intervention may affect the increase or decrease in the serum albumin levels. According to the study of the duration of nutritional promotion in bed-ridden elderly people by Fukushima et al [37]. They reported that 8 weeks post branch chain amino acid supplementation can increase serum albumin levels in patients with liver cirrhosis. This also agrees with the study of Bharadwaj et al [38] that tested albumin levels in hemodialysis patients. It was observed that the levels of albumin increased in the 8th week significantly.

In this study, most bed-ridden elderly subjects had higher levels of serum albumin after the experimental period. There were only two persons who had serum albumin levels lower than post-experiment.

It might be caused by stress from pressure ulcers, which could result in a higher metabolism (hypermetabolism), although it provides enough nutrients to meet the body's requirements. In addition, there could be factors that cause changes in the synthesis of albumin proteins, namely, increased amount of thyroid hormone that causes increased albumin breakdown as well. However, a poor hygienic condition in the environments the bed-ridden subjects' lives could make them more vulnerable to infections [35], leading to decreased levels of serum albumin. In conclusion, providing egg white as a food supplement could increase the level of serum albumin. Nevertheless, since this research has a small number of subjects, it is therefore recommended that more studies should be conducted by increasing the number of subjects.

CONCLUSION

The mean serum albumin level in bed-ridden elderly patients was increased significantly ($p < 0.05$) when compared to before the control period and after the experimental period. This study has shown that the increase of serum albumin levels could confirm the effectiveness of egg whites as a supplement in increasing the serum albumin levels in bed-ridden elderly people. Eating egg whites as a dietary supplement increases albumin protein in the body, might prevent muscle breakdown in elderly people, and reduces swelling. In addition, caregivers could effectively manage the nutritional status of elderly people who are bed-ridden with quality dependence, which may also be a guideline for further research on nutrition in bed-ridden aged seniors.

List of Abbreviation: EWFD: egg white formula diet, BTF: blenderized tube feeding, CF: commercial formula, BTF-BF: blenderized tube feeding - baby food, BTF-WF: blenderized tube feeding - whole food, HD: hemodialysis, FFP: functional food product

Conflict of Interest: The authors declare no conflict of interest in the manuscript.

Author's Contributions: All authors contributed to this study and the writing of the paper.

Acknowledgment: This research was supported by Prince of Songkla University (Grant No NUR600335M and NUR600335a)

Ethics Declarations: This study received full ethical approval from the Human Ethics Committee of the Faculty of Nursing, Prince of Songkla University (approval number: NREC 2016_002, March 3rd, 2016)

REFERENCES

1. Muurinen S, Soini H, Suominen M, Pitka¨la K: Nutritional status and psychological well-being. E Spen Eur E J Clin Nutr Metab 2010, 5: e26-e29. https://doi.org/10.1016/j.eclnm.2009.11.003
2. Nieuwenhuizen W F, Weena H, Rigby P, Hetherington MM: Older adult and patients in need of nutritional support: review of current treatment options and factors influencing nutritional intake. Clin Nutr 2010, 29:160-169. https://doi.org/ 10.1016/j.clnu.2009.09.003
3. Stanga Z: Basics in clinical nutrition: Nutrition in the elderly. E Spen Eur E J Clin Nutr Metab 2009, 4: e289-e299. https://doi.org/10.1016/j.eclnm.2009.06.019
4. Agarwalla R, Saikia AM, Baruah R: Assessment of the nutritional status of the elderly and its correlates. J Family Community Med 2015, 22:39-43. https://doi.org/10.4103/2230-8229.149588
5. Dalle S, Rossmeislova L, Koppo K: The role of inflammation in age-related sarcopenia. Front Physiol 2017, 8:1045. https://doi.org/10.3389/fphys.2017.01045
6. Deutz NEP, Bauer JM, Barazzoni R, Biolo G, Boirie Y, Bosy-Westphal A, Cederholm T, Cruz-Jentoft A, Krznariç Z, Nair KS, Singer P, Teta D, Tipton K, Calder PC: Protein intake and exercise for optimal muscle function with aging: recommendations from the ESPEN Expert Group. Clin Nutr 2014, 33:929-936. https://doi.org/10.4103/2230-8229.149588
7. Morley JE: Undernutrition in older adults. Fam Pract 2012, 29: i89-i93. https://doi.org/ 10.1093/fampra/cmr054
8. Wolfe RR, Miller SL, Miller KB: Optimal protein intake in the elderly. Clin Nutr 2008, 27:675-684. https://doi.org/10.1016/j.clnu.2008.06.008
9. Cabrerizo S, Cuadras D, Gomez-Busto F, Artaza-Artabe I, Marín-Ciancas F, Malafarina V: Serum albumin and health in older people: review and meta-analysis. Maturitas 2015, 81:17-27. https://doi.org/ 10.1016/j.maturitas.2015.02.009
10. Houston DK, Nicklas BJ, Ding J, Harris TB, Tylavsky FA, Newman AB, Lee JS, Sahyoun NR, Visser M, Kritchevsky SB: Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. Am J Clin Nutr 2008, 87:150-155. https://doi.org/ 10.1093/ajcn/87.1.150
11. Kim JH, Song H, Kim HW, Lee WY: Effects of egg white consumption on immune modulation in a mouse model of Trimellitic Anhydride-induced allergy. Korean J Food Sci Anim Resour 2015, 35: 398-405. https://doi.org/10.5851/kosfa.2015.35.3.398

12. Li-chan E, Kim HO: Structure and chemical compositions of eggs. In: egg bioscience and biotechnology Mine. A john Wiley and Sons, Inc. 2008. https://doi.org/10.1002/9780470181249.ch1
13. Ibrahim HR: Insight into the structure-function relationships of ovalbumin, ovotransferrin, and lysozyme. In: Yamamoto T, Juneja LR, Hatta H, Kim M, editors. Hen eggs: their basic and applied science. New York: CRC press, Inc.1997.
14. Obara H, Tomite Y, Doi M: Improvement in the nutritional status of very elderly stroke patients who received long-term complete tube feeding. E Spen Eur E J Clin Nutr Metab 2010, 5: e272-e276. https://doi.org/10.1016/j.eclnm.2010.09.008
15. Wada S, NakajI S, Umeda T, Takahashi I, Oyama T, Chinda D, Sugawara K, Shimoyama T, Sakamoto J, Fukuda S: Nutritional effects of supplement liquid formula diet with dietary fiber on elderly bed-ridden patients. Tohoku J Exp Med. 2004, 203:9-16. https://doi.org/ 10.1620/tjem.203.9
16. AOAC: Official methods of analysis (17th ed.) Gaithersberg, Maryland: Association of Official Analytical Chemists. 2000.
17. Food Safety Authority of Ireland: Guidance Note No. 18. Validation of Product Shelf-Life. (Revision 1): The Exchange, George's Dock, IFSC, Dublin. 2019
18. Wade DT, Collin C: The Barthel ADL Index: A standard measure of physical disability? Int Disabil Stud. 1988, 10: 64-67. https://doi.org/ 10.3109/09638288809164105
19. U.S. Food and Drug Administration. Compliance program guidance manual 7321.002. Rockville, MD. 2006. [https://www.fda.gov/media/71685/download] Retrieved February 8, 2022.
20. Tri QH, Murphy KM, Drapala KP, O'Callaghan TF, Fenelon MA, 'Mahony JA, McCarthy NA: Effect of pH and heat treatment on viscosity and heat coagulation properties of milk protein concentrate. Int Dairy J 2018, 85: 219-24. https://doi.org/10.1016/j.idairyj.2018.05.012
21. Phillips SM, Chevalier S, Leidy HJ: Protein requirements beyond the RDA: implications for optimizing health. Appl Physiol Nutr Metab 2016, 41:565-72. https://doi.org/10.1139/apnm-2015-0550
22. Stadelman WJ, Cotterill OJ: Egg Science and Technology, 4th ed. Westport, CT, USA: Avi Publ. Co., 2001.
23. Kovacs-Nolan JKN, Phillips M, Mine Y: Advances in the value of eggs and egg components for human health. J Agric Food Chem 2005, 53:8421-8431. https://doi.org/10.1021/jf050964f
24. Sullivan MM, Sorreda-Esguerra P, Platon MB, Castro CG, Chou NR, Shott S, Comer GM, Alarcon P: Nutritional analysis of blenderized enteral diets in the Philippines. Asia Pac J Clin Nutr 2004, 13:385-391.
25. Hron B, Rosen R: Viscosity of commercial food-based formulas and home-prepared blenderized feeds. J Pediatr Gastroenterol Nutr 2020, 70(6): e124-e128. https://doi.org/10.1097/MPG.0000000000002657
26. Singer P, Berger MM, Berghe GVD, Biolo G, Calder P, Forbes A, Griffiths R, Kreyman G, Leverve X, Pichard C: ESPEN Guidelines on parenteral nutrition: intensive care. Clin. Nutr. ESPEN 2009, 28:387-400. https://doi.org/10.1016/j.clnu.2009.04.024
27. Chernoff R: An overview of tube feeding: from ancient times to the future. Nutr Clin Pract 2006, 21(4):408-410. https://doi: 10.1177/0115426506021004408
28. Johnson TW, Milton DL, Johnson K, Carter H, Hurt RT, Mundi MS, Epp L, Spurlock AL. Comparison of microbial growth between commercial formula and blenderized food for tube feeding. Nutr Clin Pract 2019, 34(2):257-263. https://doi.org/10.1002/ncp.10226
29. Klek S, Szybinski P, Sierzega M, Szczepanek K. Sumlet M. Kupiec M. Szozda EK, Steinhoff-Nowak M. Figula Z. Kowalczyk T. Kulig J: Commercial enteral formulas and nutrition support teams improve the outcome of home enteral tube feeding. J Parenter Enteral Nutr 2011, 35(3):380-385. https://doi: 10.1177/0148607110378860
30. Baniardalan M, Sabzghabaee AM, Jalali M, Badri S: Bacterial safety of commercial and handmade enteral feeds in an Iranian teaching hospital. Int J Prev Med 2014, 5(5):604-610.
31. Mohd Adam MAS, Gan CY: Dual-function peptides derived from egg white ovalbumin: bioinformatics identification with validation using in vitro assay. J Funct Foods 2020, 64:103618. https://doi.org/10.1016/j.jff.2019.103618
32. Levitt D, Levitt M: Human serum albumin homeostasis: a new look at the roles of synthesis, catabolism, renal and gastrointestinal excretion, and the clinical value of serum albumin measurements. Int J Gen Med. 2016, 9:229-255. https://doi.org/10.2147/IJGM.S102819
33. Kalantar-Zadeh K, Kilpatrick RD, Kuwae N, McAllister CJ, Alcorn Jr H, Kopple JD, Greenland S: Revisiting mortality predictability of serum albumin in the dialysis population: time dependency, longitudinal changes and population-attributable fraction. Nephrol Dial Transplant 2005, 20:1880-8. https://doi.org/ 10.1093/ndt/gfh941

34. Daugirdas JT: Removal of phosphorus by hemodialysis. Semin Dial 2015, 28:620-623. https://doi.org/10.1111/sdi.12439
35. English KL, Paddon-Jones D: Protecting muscle mass and function in older adults during bed rest. Curr Opin Clin Nutr Metab Care 2010,13:34-39. https://doi.org/10.1097/MCO.0b013e328333aa66
36. Martirosyan DM, Lampert T, Ekblad M: Classification and regulation of functional food proposed by the functional food center. Functional Food Science 2022; 2(2): 25-46. https://www.doi.org/10.31989/ffs.v2i2.890
37. Fukushima H, Miwa Y, Shiraki M, Gomi I, Toda K, Kuriyama S, Nakamura H, Wakahara T, Era S, Moriwaki H: Oral branched-chain amino acid supplementation improves the oxidized/reduced albumin ratio in patients with liver cirrhosis. Hepatol Res 2007, 37: 765-770. https://doi.org/10.1111/j.1872-034X.2007.00123.x
38. Bharadwaj S, Ginoya S, Tandon P, Gohel TD, Guirguis J, Vallabh H, Jevenn A, Hanouneh I: Malnutrition: laboratory markers vs nutritional assessment. Gastroenterol Rep 2016, 4:272-280. https://doi.org/10.1093/gastro/gow013