Stability of vitamins and minerals in fortified rice two year shelf-life study under real-life conditions

In collaboration with the United Nations World Food Programme

Dr. Werner Nader, Eurofins consultant

October 6th, 2025

anuga

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Testing for Life

MICRONUTRIENT DEFICIENCIES PLACE A HEAVY BURDEN ON THE HEALTH AND ECONOMY OF NATIONS

up to 5% [1-5]

of GDP is lost as a result of micronutrient deficiencies

over 340 million [6]

preschoolers are deficient in at least one micronutrient

26,800 [7]

yearly deaths due to vitamin A and zinc deficiencies

Well over 2 billion people, including 1 in 2 preschool-aged children and 2 in 3 women of reproductive age (together one-third of the world's population) suffer from micronutrient deficiencies [8]

260,000 [9]

global birth defects due to maternal folate deficiency

45% [10]

child deaths caused by undernutrition

- 250 000–500 000 vitamin A-deficient children become blind every year. Significant morbidity and mortality from common childhood infections. Contributes to maternal mortality and other poor outcomes of pregnancy and lactation. Diminishes the ability to fight infections.
- Low- and middle-income countries bear the disproportionate burden of micronutrient deficiencies.

Sources: World Food Programme & World Health Organisation

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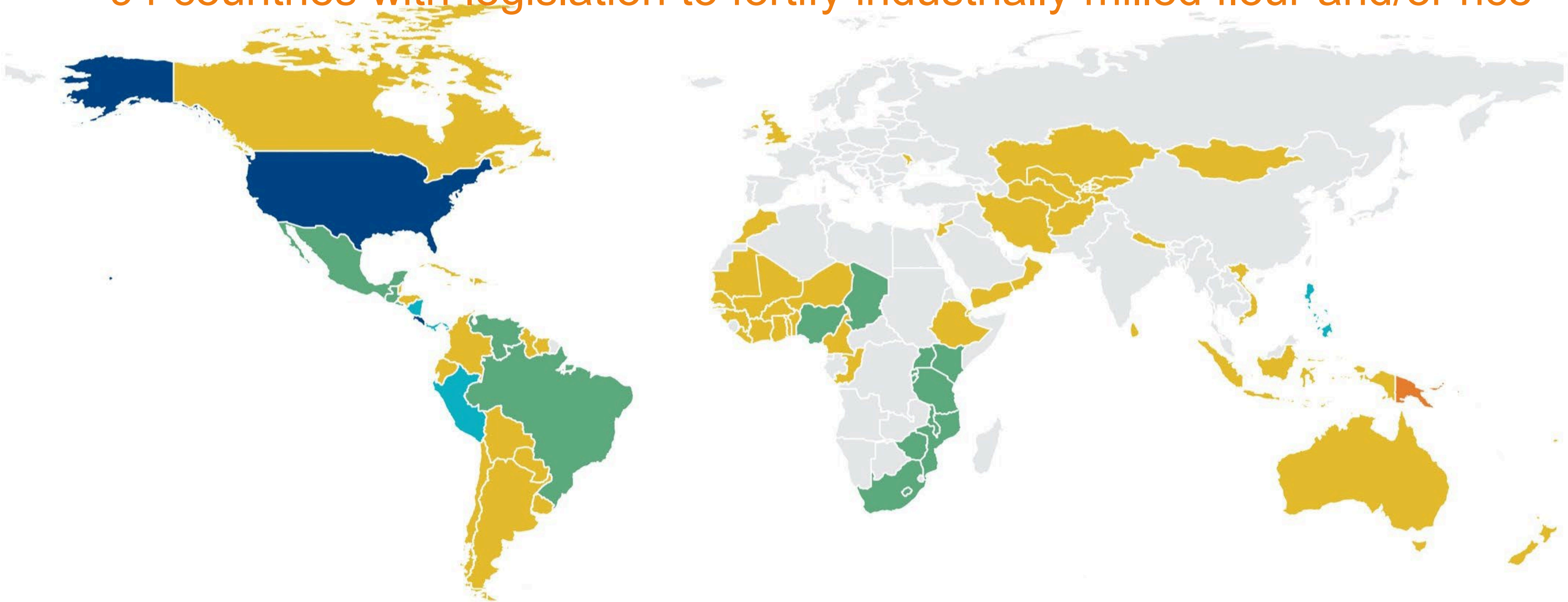
94 countries with legislation to fortify industrially milled flour and/or rice



LEGEND

Mandatory cereal grain fortification legislation

- No mandatory legislation or data not available
- Wheat flour
- Rice
- Wheat flour and maize flour
- Wheat flour and rice
- Wheat flour, maize flour, and rice

- 69 countries have legislation for **wheat flour alone**
- 17 countries have legislation for **wheat flour and maize flour**
- 5 countries have legislation for **wheat flour and rice** (Nicaragua, Panama, Peru, Philippines, Solomon Islands)
- 2 countries have legislation for **wheat flour, maize flour, and rice** (Costa Rica and the United States)
- 1 country has legislation for **rice alone** (Papua New Guinea)

Source: Food Fortification Initiative. Global Progress. Accessed 28.09.2025

94 countries with legislation to fortify industrially milled flour and/or rice

Costa Rica fortifies rice with folic acid, thiamine, vitamin B12, niacin, vitamin E, Se and Zn

Philippines mandates iron fortification

USA: Fortification with folic acid, 2 x amount as before milling. Rules for enriched rice in the CFR 137.350: Not less than 2.0 milligrams (mg) and not more than 4.0 mg of thiamin, not less than 1.2 mg and not more than 2.4 mg of riboflavin, not less than 16 mg and not more than 32 mg of niacin or niacinamide, not less than 0.7 mg and not more than 1.4 mg of folic acid, and not less than 13 mg and not more than 26 mg of iron (Fe).

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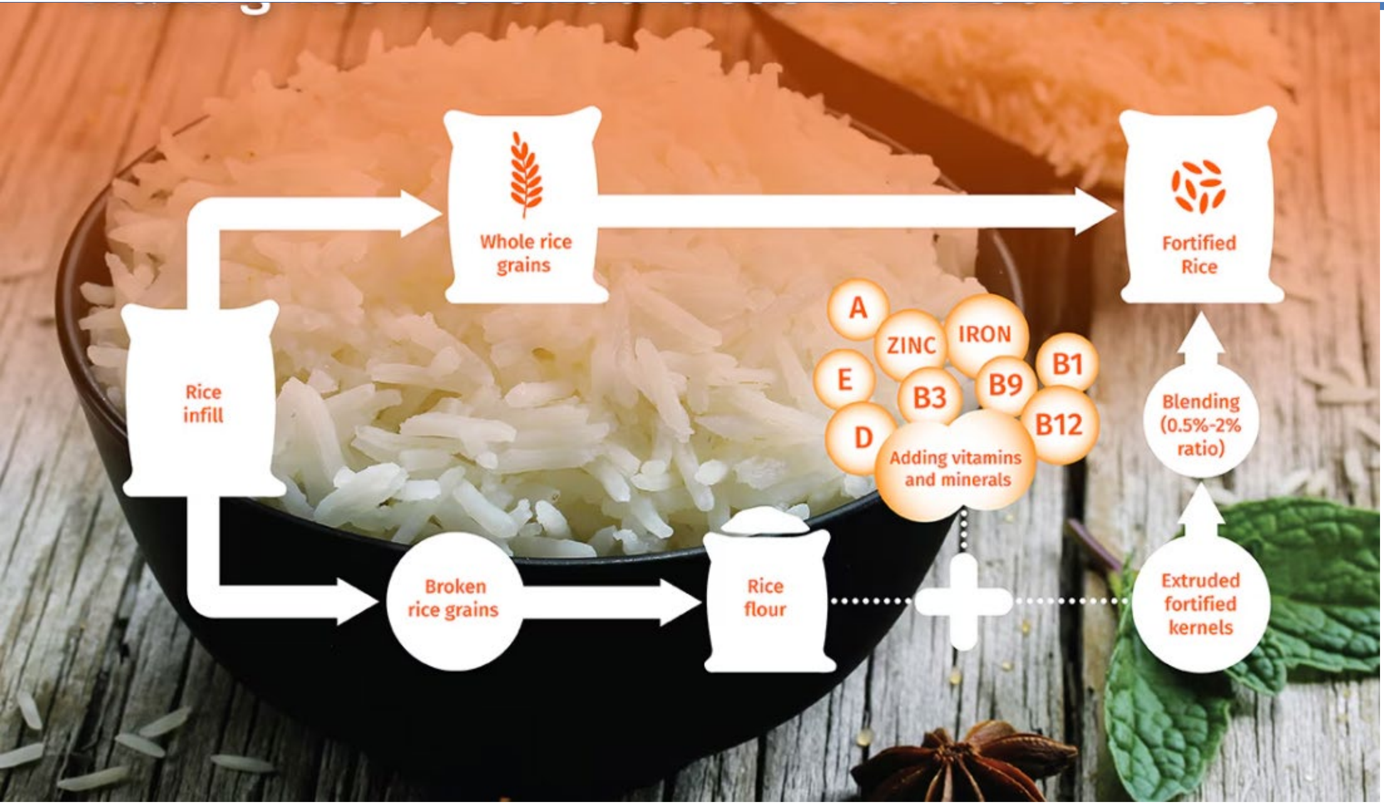
Production and mixing of hot extruded FRKs



Source: DSM, https://www.dsm-firmenich.com/en/businesses/health-nutrition-care/news/talking-nutrition/everything-you-need-to-know-about-fortified-rice.html

Vitamins and minerals in rice

Micronutrient	Source in premix kernels (FRKs)	Brown rice[a]		White rice[a]		Parboiled rice[b]	Cooked white[b]	Cooked parboiled[b]	WFP specified fortified rice	
		min	max	min	max				min	max
		(mg/kg)								
Vitamin A	retinyl palmitate								1.95	3.12
Vitamin B12	cyanocobalamin	0							0.013	0.020
Vitamin C										
Vitamin B1	thiamine mononitr.	3.2	5.1	0.4	0.9	2.1	0.3	0.5	6.5	9.75
Vitamin B2		0.5	1.3	0.22	0.5		0.1	0.1		
Vitamin B3	niacinamide	46	58	10	15	42	3	7	91	109.2
Vitamin B5		17		6.2	6.4	7.8	0.9	0.9		
Vitamin B6	pyridoxine hydrochl.	1.95	10	1.1	2	1.8	0.3	0.3	7.8	11.7
Vitamin B7		0.12		0.03		0.03	0.004	0.004		
Vitamin B9	folic acid	0.16		0.11	1	0.18	0.04	0.06	1.69	2.54
Vitamin E		2.29	7.98	1.84		0.4	0.1	0.1		
Iron	ferric pyroph.	20	36	6.5	12	3.7	0.4	0.5	40	48
Zinc	zinc oxide	16		8.1	13	11	4	3	60	72

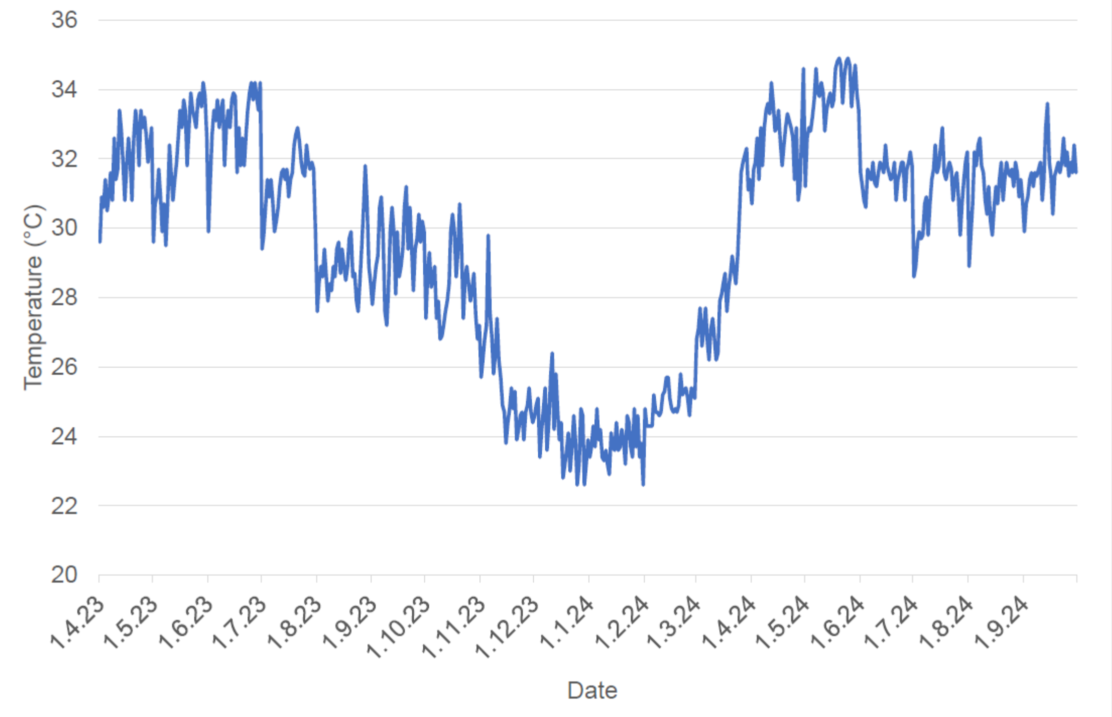
[a] Souci, Fachmann & Kraut, 2024
[b] McCance and Widdowson's composition of foods integrated dataset, 2010

Storage of samples at LT Foods Limited, Mandideep

- Hot extruded and coated fortified rice kernels (FRKs) packed in 25 kg PE inner liner and in laminated metallized bags
- Rice fortified with hot extruded and coated FRKs packed in 10 kg 90 micron polyethylene (PE), woven polypropylene (PP) and USAID hybrid (perforated kraft paper laminated with biaxially orientated nylon) bags
- All under industrial real-life conditions. Fortified rice after industrial mixing with FRKs

Mandideep: Köppen-Trewartha climate classification Bsh,
Dry – semi arid -hot

Source: Bindhu et al., 2020, International Journal of Climatology



Analytical method developed by Eurofins Vitamine Competence Center, Vejen, Denmark

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AKADÉMIAI KIADÓ

Acta Chromatographica

DOI:
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ORIGINAL RESEARCH PAPER

Check for updates

Quantification of retinyl palmitate, thiamine, niacin, pyridoxine, folic acid, cyanocobalamin, zinc, and iron by chromatographic methods in fortified kernels and fortified rice

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ABSTRACT

This study presents the optimization and validation of methods for the analysis of retinol, thiamine, niacin, pyridoxine, folic acid, cyanocobalamin, zinc, and iron in fortified kernels (coated and extruded) and in fortified rice. The analyses were performed by HPLC-UV/FLD/MS and ICP-OES. The optimized methods showed good resolution of the analyte peaks, excellent recovery (87–108%), reproducibility with relative standard deviation (SD) of analyte content between 1.8 and 11% and high correlation coefficient of the calibration curves ($R^2 > 0.997$). Limit of detection was from 2.8 E-4 mg/kg for pyridoxine to 1.26 mg/kg for zinc and limit of quantification was from 9.2 E-4 mg/kg for pyridoxine to 4.21 mg/kg for zinc. Thereby the optimized methods demonstrated reliability and sensitivity in the detection and quantification of these micronutrients and that they are suitable for routine analysis of fortified kernels (coated and extruded) and fortified rice.

nutrients

MDPI

Article

Stability of Vitamin A, Iron and Zinc in Fortified Rice during Storage and Its Impact on Future National Standards and Programs—Case Study in Cambodia

Khov Kuong [1,†], Arnaud Laillou [2,*,†], Chantum Chea [3], Chhoun Chamnan [1], Jacques Berger [4] and Frank T. Wieringa [4,†]

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Issue: *Technical Considerations for Rice Fortification in Public Health*

Stability and retention of micronutrients in fortified rice prepared using different cooking methods

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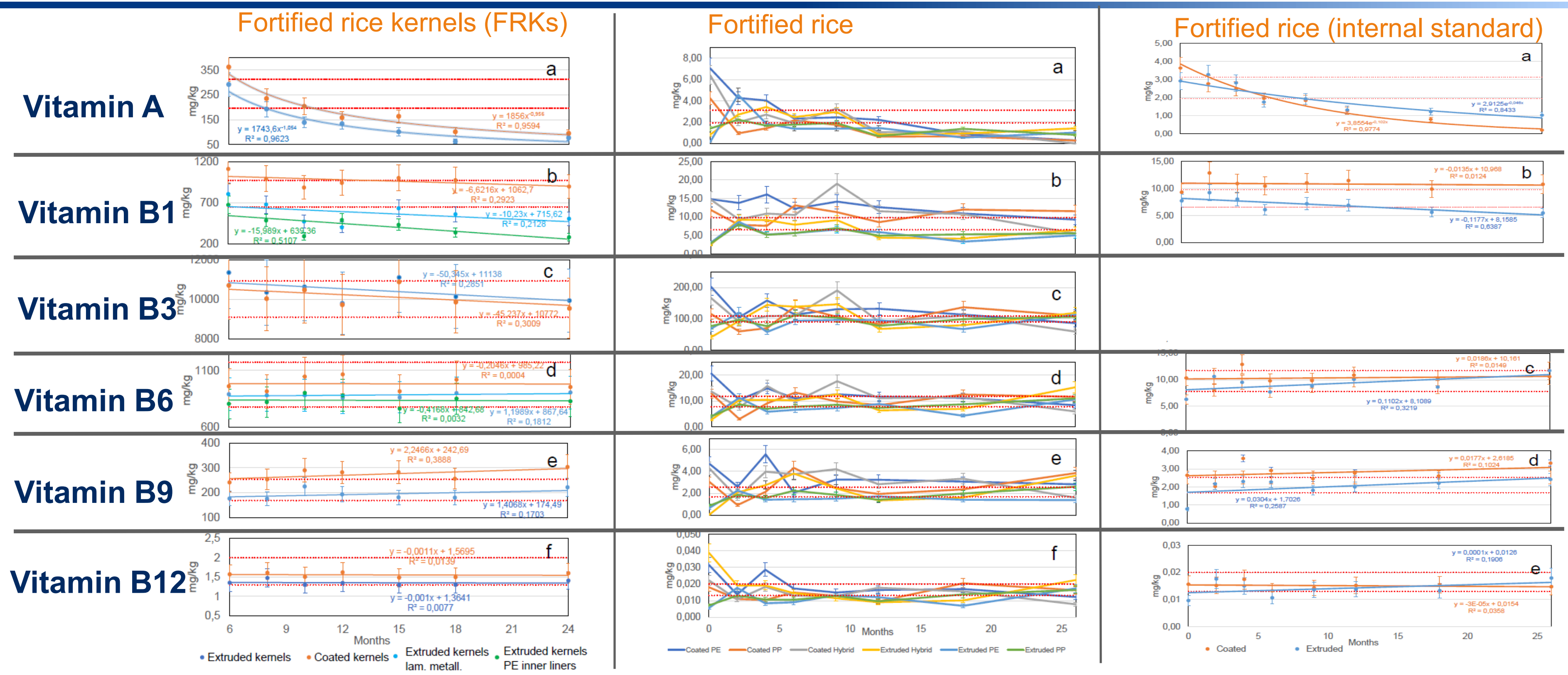
Fortified rice holds great potential for bringing essential micronutrients to a large part of the world population However, it is unknown whether differences in cooking methods or in production of rice premix affect the final amoun of micronutrient consumed. This paper presents a study that quantified the losses of five different micronutrient (vitamin A, iron, zinc, folic acid, and vitamin B12) in fortified rice that was produced using three different technique (hot extrusion, cold extrusion, and coating) during cooking and five different cooking methods (absorption metho with or without soaking, washing before cooking, cooking in excess water, and frying rice before cooking). Fortifie rice premix from six different producers (two for each technique) was mixed with normal rice in a 1:100 ratio. Each sample was prepared in triplicate, using the five different cooking methods, and retention of iron, zinc, vitamir

Storage stability study of FRKs and fortified rice



Resume

- **Vitamin A** decays rapidly with
  - half-lifes of 6.5 months (coated) and 5.5 months (extruded) in FRKs
  - half-lives of 6.8 (coated) and 15.1 months (extruded) in fortified rice
- **Vitamin B1** decays in extruded FRKs stored in metallized paper bags and rice fortified with these in all packaging types with half-lives of 20 and 34 months, but is quite stable in coated FRKs
- **Formulas** were derived to predict vitamin A and B1 concentrations at different storage times based on the reaction kinetics of the decay
- **Vitamins B3, 6, 9, 12 and minerals iron & zinc** within specifications over 2 years
- **WFP mixing tolerance** for FRKs into rice is ± 15 %, but is a challenge at industrial scale and was exceeded contributing to the high variations of analytical results
- **Analytical control of vitamin and mineral concentrations** in fortified rice requires an internal standard to correct for mixing variations

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- **Vita** ... ed with ... ble in c ...

Vitamin A in FRKs: $y = a * x^{-b}$

Vitamin A in FR: $y = a * e^{-k\,x}$

Vitamin B1 in extruded FRKs: $y = -a\,x + b$

- **For** ... ge time ...
- **Vita** ...
- **WFP mixing tolerance** for FRKs into rice is ± 15 %, but is a challenge at industrial scale and was exceeded contributing to the high variations of analytical results
- **Analytical control of vitamin and mineral concentrations** in fortified rice requires an internal standard to correct for mixing variations

Practical implications

- Changes were made by the WFP to the technical specifications for FRKs, which are publicly accessible under https://foodsafetyqualitypublic.manuals.wfp.org/docs/specifications-index
- Removal of vitamin A from specifications
- FRKs can be stored up to 24 months when purchased by WFP
- Shelf-life of fortified rice is defined based on the remaining shelf-life of the fortified rice kernels at the time they are blended with milled rice, plus 6 months but must not exceed 30 months from the production date of the fortified rice kernels
- When purchased directly, the shelf-life of fortified rice must not exceed 18 months
- Stricter controls are necessary over industrial mixing processes
- The analytical method introduced in the study with internal standards could be adopted more widely in the industry to improve quality control
- Further research is needed to understand how vitamin and mineral levels in FRKs and fortified rice would evolve over longer periods of two years
- Need to optimize FRK formulations to improve stability of micronutrients

Contributors to the project

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