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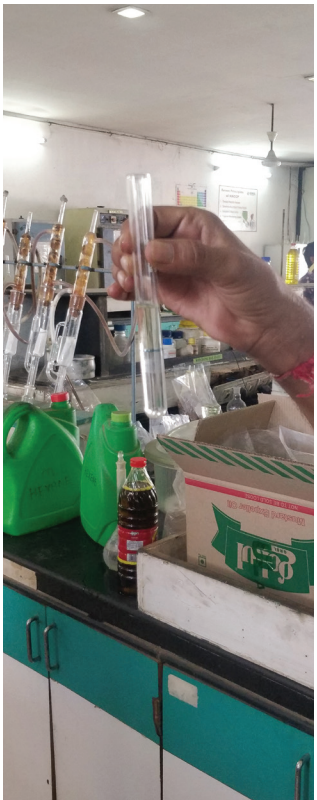

THE INDUSTRIAL PROCESSES OF EDIBLE OIL FORTIFICATION

An overview of technical requirements and variations adapted by the industry

The Industrial Processes of Edible Oil Fortification

An overview of technical requirements and variations adapted by the industry

Publisher

KHPT
IT Park, 5th Floor
1-4, Rajajinagar Industrial Area
Behind KSSIDC Admin Office
Rajajinagar, Bengaluru
Karnataka - 560 044

Ph: + 91 80 4040 0200
Fax: + 91 80 4040 0300
Email: khptblr@khpt.org
Website: www.khpt.org

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Acknowledgements

Study Team - KHPT
Ms. Agnita R
Mr. Bhubananandana Patnaik
Mr. Gururaj Patil
Ms. Jagatheeshwari
Mr. Jalinder Shinde
Ms. Jaya Tripathi
Mr. Rashid Nazki
Mr. Sadhish Jain
Mr. Satheesh Chandran
Mr. Sharad Yadav
Mr. Shreeraj Manampadi
Mr. Sooraj Tigga
Mr. Subhash Moghe
Ms. T Usharani
Dr. Troy Cunningham

Advisory- GAIN
Ms. Deepti Gulati
Ms. Ruchi Sareen
Ms. Shakun Sharma

Editorial
Ms. Vrinda Manocha

Design and layout
Mr. Anilkumar Rampur

Photography Credits
Fortification Project Team

PREFACE

The purpose of this document is to provide a comprehensive overview of different types of processes adopted by edible oil industries to fortify edible oils. The primary goal of this document is to share different technical requirements surrounding the edible oil fortification process with edible oil industries/manufacturers. It includes information about the different types of equipment which can be installed, as well as provides a description of the ways to fabricate customized equipment using local labour and materials which are proven to be cost-effective. Edible oil industries across states adopt different methods of fortification based on their infrastructure. There are different variations within standard batch fortification or online fortification methods. It is important to understand these processes and their possible impact on the quality of fortification. Thus, we have attempted to document different variations in fortification methods employed by the industry and study the differences in terms of set-up required and cost involved for each of the methods.

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BACKGROUND

The Production and Consumption Pattern of Edible Oils in India

India is blessed to have a wide range of oilseed crops growing in its different agro-climatic zones. Mustard, soybean, groundnut, sunflower, rapeseed, sesame, safflower, flax seed, castor etc. are the major traditionally-cultivated oil crops. Coconut and palm are the most important among the plantation crops. Among the less-consumed oils, rice bran oil and cottonseed oil are the most important. India is one of the largest producers and importers of oilseeds in the world. Although the production of edible oil in India has increased over the last decade, so has the consumption, leading to a proportionate rise in the import of edible oil. According to a report released by the Department of Food and Public Distribution, Ministry of Consumer Affairs, Food and Public Distribution, Government of India, the total production of edible oils from all the domestic sources in India for the year 2019 -2020 was 106.55 lakh tons, whereas the total quantity of edible oils imported in the year was reported to be 134.16 lakh tons.[1]

The Indian population has developed specific preferences for certain oils depending largely upon the oils available in that particular geography. For instance, people in the south and west prefer coconut and groundnut oil, while those in the east and north use mustard oil. Through modern technological means such as refining and bleaching, all the oils have been rendered practically colourless, odourless and tasteless, and therefore have become easily interchangeable in the Indian kitchen.

The edible vegetable oil industry in India is classified mainly into three categories - small scale expellers, medium scale re-packers, large scale oil refineries and solvent extract units. Small scale industries like local expellers extract the oil from oil seeds using mechanical pressing methods, and filter the oil and pack it to sell in the market. Medium scale re-packers procure the refined or filtered oil in bulk tankers from big refineries and pack it at their facilities to sell in the market. In large scale oil refineries and solvent extraction units, industrial processes are being carried out that convert crude oil into high-quality oil products that are fit for human consumption.

Source: Ashwini Chaudhary/Unsplash

[1]https://dfpd.gov.in/oil-division.htm

Need for Edible Oil Fortification

A diet adequate in the essential micronutrients (vitamins and minerals) is necessary for proper growth and development. These essential micronutrients are required in limited amounts (a few micrograms to milligrams a day). However, deficiencies in essential micronutrients may have serious consequences on the health, including on reproduction, immune system response, physical and mental growth, and energy metabolism. In many developing nations including India, malnutrition, coupled with high rates of disease, results in elevated instances of micronutrient deficiencies. Approximately one-third of the world population is affected by micronutrient deficiencies (vitamins and mineral deficiencies) also known as Hidden Hunger[2]. In low-and middle-income countries, approximately one-third of children below the age of 5 years are afflicted with Vitamin A deficiency (VAD)[3]. It is predicted that about 3,30,000 child deaths occur due to VAD each year in India[4]. Inhabitants of less-developed countries, especially women of child-bearing age, are more susceptible to VAD. Vitamin D is a fat soluble vitamin and refers to both Vitamin D3, i.e., cholecalciferol, and Vitamin D2, i.e., ergocalciferol. Vitamin D can be synthesized endogenously. About 90% of the required Vitamin D can be synthesized in the skin when exposed to the sun. It is needed for the mineralization of bone, muscle

[2]Stevens GA, Bennett JE, Hennocq Q et al. (2015) Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013: a pooled analysis of population-based surveys. Lancet Glob Health 3, e528–e536.

[3]Thompson B & Amoroso L (editors) (2014) Improving Diets and Nutrition: Food-Based Approaches. Rome and Wallingford: FAO and CAB International.

[4]Akhtar, S., Ahmed, A., Randhawa, M. A., Atukorala, S., Arlappa, N., Ismail, T., & Ali, Z. (2013). Prevalence of vitamin A deficiency in South Asia: causes, outcomes, and possible remedies. Journal of health, population, and nutrition, 31(4), 413–423. https://doi.org/10.3329/jhpn.v31i4.19975

[5]Aparna, P., Muthathal, S., Nongkynrih, B., & Gupta, S. K. (2018). Vitamin D deficiency in India. Journal of family medicine and primary care, 7(2), 324–330. https://doi.org/10.4103/jfmpc.jfmpc_78_18

contraction, nerve conduction, immune health and general cellular functions in human body. The prevalence of Vitamin D deficiency is reported worldwide, both in sunshine-deficient and sunshine-sufficient countries. Still, it is the most under-diagnosed and under-treated nutritional deficiency in the world. Community based Indian studies from the past decade done on apparently healthy controls reported a prevalence ranging from 50% to 94%[5]. VAD affects millions of preschool-age children and pregnant women worldwide. It is the leading cause of preventable blindness in children, resulting in thousands of cases of blindness every year. VAD also leads to night blindness in pregnant women and increases the risk of maternal mortality. One of the most cost-effective public health interventions to reduce the risk of Vitamin A deficiency is Large-Scale Food Fortification (LSFF). LSFF is the addition of vitamins and minerals (e.g. Vitamin A, Vitamin D, iron, zinc, and folic acid) to staple foods like wheat or rice, edible oils and fats, salt and milk. Edible oils and fats are commonly fortified with the fat-soluble vitamins A and D. LSFF works best where a food is

- Widely consumed by populations regardless of socio-economic status
- Centrally manufactured or processed.

Edible oils and fats are such foods, since they are consumed in almost every household worldwide in relatively small, but consistent quantities of about 12-33 grams per person per day. Furthermore, in most countries, edible oils and fats are processed centrally by medium and large-scale producers, which makes it easier to implement and monitor the fortification process. Fortification of margarine with Vitamin A was first mandated over a hundred years ago in Denmark, which practically eliminated cases of xerophthalmia, an eye disease associated with VAD. Vitamin D fortification had a similar effect on the incidence of rickets, which is associated with Vitamin D deficiency. United States and Great Britain quickly followed Denmark and mandated the fortification of margarine. In the middle of the 20th century, India and Pakistan also mandated the fortification of edible oils with vitamins A and D in some provincial areas. Today, 27 countries have mandated the fortification and 11 countries have introduced the voluntary fortification of edible oils.[6]

As a complement to dietary diversification and supplementation strategies, the food fortification of commonly eaten staple foods in a country increases the threshold of micronutrient intake in the population. The concept of nutrient fortification of foods was introduced in India in 1953 with the mandatory fortification of vanaspati with Vitamin A to make it nutritionally comparable with ghee, after recommendations from the Ghee Adulteration Committee. A similar recommendation was also made by the Nutrition Advisory Committee of the Indian Council of Medical Research in 1953. Then, under the legislation S.R.O.-2103, vanaspati fortification was made mandatory in India. At present, India is considering announcing mandatory fortification of all edible refined oils with vitamins A and D.

Fortification of edible oils is technologically feasible. Compared to other food staples, they are also relatively easy to fortify. Oil-soluble vitamins (A and D) are readily miscible with the oils. Custom premixes or blends of vitamins A and D are available commercially to meet the specific requirements of oil fortification. As vitamins A, D and E are fat soluble, they can be uniformly distributed in oil without a need for elaborate equipment. It is important that a good quality oil is used for fortification. If the oil is partially or fully oxidized to begin with, the stability of the vitamins will be compromised. The oil should contain a sufficiently high amount of antioxidants, either added or naturally present as tocopherol. Once the oil is fortified, it is packaged and cooled. It is important that air tight, and preferably opaque, packaging be used, so that the oil will be protected from air and light.

[6]https://fortificationdata.org/interactive-map-fortification-legislation/

FSSAI Standards for Edible Oil Fortification

As per the Food Safety and Standards (Fortification of Foods) regulations, 2018, vegetable oil shall be fortified with the following micronutrients, at the levels given in the table below:

Micronutrient	Level of Nutrients (per 100 gram of oil)	Source of Nutrients
Vitamin A	600-990 ug RE	Retinyl acetate or Retinyl palmitate
Vitamin D	11-16 ug	*Cholecalciferol or *Ergocalciferol (*Only from Plant Source)
Vitamin A (retinol): 1 IU= 0.3 µg RE (Retinol Equivalent); Vitamin D (Cholecalciferol or Ergocalciferol), only plant source: 1 IU= 0.025 µg		

EDIBLE OIL FORTIFICATION TECHNOLOGY

In the fortification process, a known quantity of vitamin is added to the oil at the filling line of the oil manufacturing chain, before packaging. The vitamins can be added in one of two ways, through a continuous process or through a batch system. In a continuous process, the pre-blend is stored in premix tanks of 50 kg to 100 kg. These tanks are equipped with agitators to keep a uniform distribution of premix in the oil. A dosing pump that is synchronized with the flow rate of oil determines the amount of pre-blend added. Further blending of the pre-blend with the oil takes place at an appropriate point at the filling point to ensure the optimum distribution of the pre-blend through the oil before final packaging. In the batch fortification process, the addition can be done through mixing the pre-blend in an agitator tank or recirculating the oil using a motor.

Fortification is the process of adding vitamin premix to edible oil in a controlled manner. It is a two-step process:

Preparing the pre-blend

Pre-blend is the simple dilution prepared using vitamin premix and a known quantity of edible oil to be fortified (usually 5-10 litres for small batches and 50-100 litres in case of continuous dosing, depending on fortification processes). Despite the simple principle of oil fortification, there are few major concerns, the pre-blend preparation being one. The vitamin premix should be diluted in oil substrate to form a pre-blend which is easy to handle and mix without high risk of error. Dilution should conform to the highest quality control procedures and is better performed by the production staff who are technically trained.

The rate of addition of the premix is fixed based on batch size. The standard ratio of premix and oil is 1:50 i.e. 100 g premix is required to fortify 5000 kg of oil. As a first step, the premix is required to be heated in a water bath at 45 degrees Celsius for 10-15 minutes. If the industry does not have a water bath in its facility, the premix bottle can be placed for 10-15 minutes in a utensil filled with water, with the temperature of water maintained between 40-45 degree Celsius, and checked using a laboratory/ food thermometer. Then, the pre-blend is prepared with some amount of oil to be fortified. There are different types of pre-blend preparation methods depending on the physical and economical capacity of the oil mills. During our project intervention, we have come across many kinds of customized pre-blend tank set-ups across states, including the manual method of mixing. The oil industries are using these preparation methods to ensure the uniform mixing of premix in the aliquot oil to prepare the pre-blend.

A. Manual preparation of pre-blend: In this method, the pre-heated premix is added gradually to aliquot oil in a stainless steel bucket. Then the mixture is stirred continuously with the help of a stainless-steel rod or spoon in a clockwise direction for 10-15 minutes. To ensure that the full quantity of the premix present in the bottle is used, rinsing of the premix bottle is done at least three times with the aliquot oil and the pre-blend is prepared.

B. Low-cost customized pre-blend tank: This tank is designed to prepare pre-blend using basic household equipment like a curd churner and stainless steel tank. In this type of setup, a stainless-steel tank (capacity of 22 litres) with an internal depth of 11 inches is utilized as a pre-blend tank. An electric agitator (0.5 hp motor), used as a curd percolator otherwise, with a steel rod (9 inches long) and four sharp-edged blades is used to mimic the process of an industrial agitator. To control number of rotations per minute (rpm), the agitator is connected with a device known as "Speed Control Dimmer", which allows the adjustment of rotations in tank. The rpm counts currently in use by oil industries are 40 rpm. There is an outlet in the lower portion of the pre-blend tank for supplying the pre-blend into the main blending tank/circulation tank. This outlet is connected with a stainless-steel pipeline to the main tank. The transfer of the pre-blend from the pre-blend tank to the main blending/circulation tank is achieved using a motor pump of 0.5 hp. To fortify 5 metric tons of edible oil, 10 litres of the same oil is taken in the pre-blend tank and 100 g of Vitamin A-D premix is added to it. Now, the pre-blend is prepared by stirring this mixture using an electric agitator for 25-30 minutes. The pre-blend is then transferred via steel pipeline using an electric motor pump to the main blending/circulation tank. The estimated cost of this kind of set-up is around INR 5,000. These kinds of set-ups are mainly used by small scale edible oil industries e.g. re-packers, blenders etc.

Pre-blend tank connected to main tank

Speed Dimmer

C. Automated pre-blend tank: This pre-blend tank is designed using industrial fabrication processes. In these type of setups, one or two stainless-steel tanks are utilized as a pre-blend tank. An agitator having six or more blades on a perpendicular steel rod is installed within the tank. To regulate time and speed, the agitator is connected with a regulator device and connected with an electric supply. There is an outlet in the lower portion of the pre-blend tank for supplying the pre-blend into the main blending tank/circulation tank. This outlet is connected with a stainless-steel pipeline to the main tank. The transfer of the pre-blend from the pre-blend tank to the main blending/circulation tank is achieved using a motor pump. To fortify 5 metric tons of edible oil, 5 litres of the same oil is taken in one of the pre-blend tanks and 100 g of vitamin premix is added to it. Now, the agitator is allowed to mix the solution by supplying electricity for 5 -10 minutes. Pre-blend is then transferred via pipelines using an electric motor pump to the main blending/circulation tank. The estimated cost of this kind of set-up is around INR 50,000. These kinds of set-ups are basically used by medium scale edible oil re-packers and blending units.

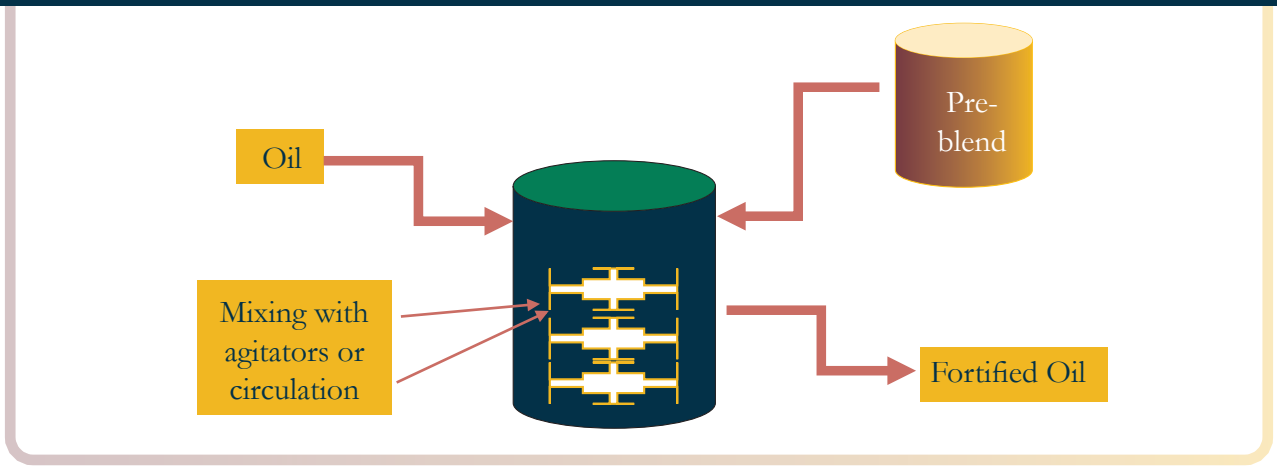
Automated Pre-blend Tank

Points to note :

- The pre-blend is prepared separately and then added to the main oil tank and agitated for uniform mixing.
- Fresh pre-blend needs to be prepared as per the requirement of particular batch.

• Mixing the pre-blend with edible oil (Batch Process)

In the batch process, a precise quantity of pre-blend (premix diluted with oil) is added directly via pipeline or manually to a run tank equipped with agitators or having a circulation system, and mixed thoroughly for at least 30-40 minutes before filling.

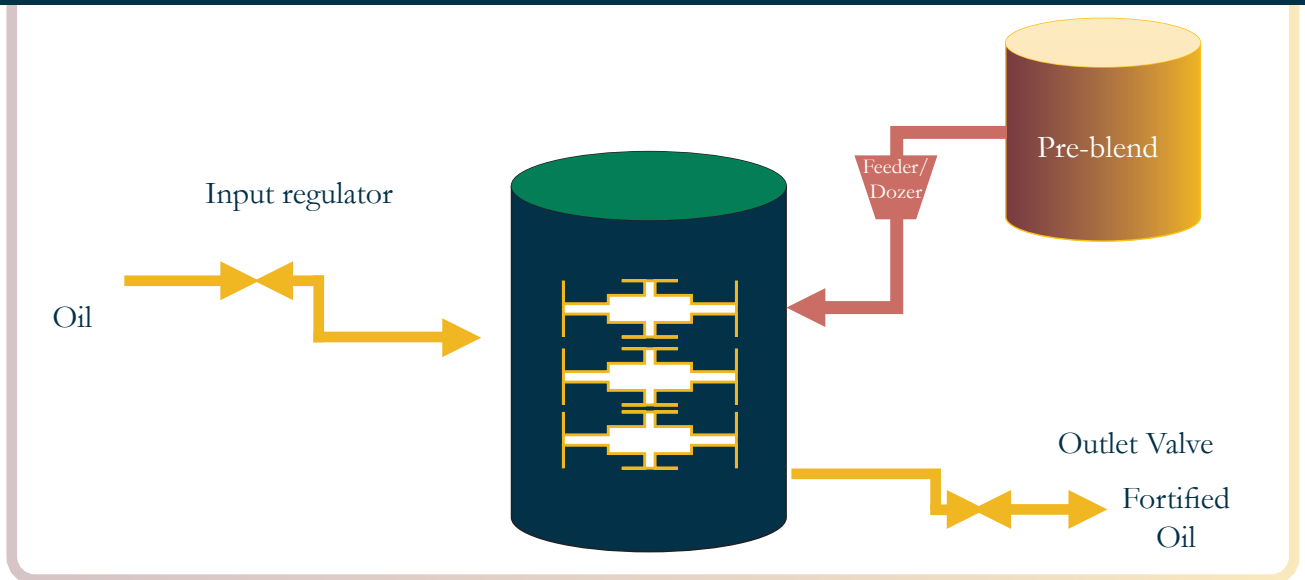


A. Mixing with Agitators: The main tank usually has a setup comprised of a gear box and a motor pump, the purpose of which is to provide controlled agitation of the mixture within the tank. The pre-blend and 5 metric tons of oil is churned using an agitator that rotates at 70-90 rpm, usually for 30 - 40 minutes. At this point, it is monitored so that the agitator rotations are maintained at a fixed speed to facilitate homogenous and uniform mixing. An outlet on the lower side of main blending/circulation tank is present, through which fortified oil is sent to a holding/storage tank using stainless steel pipelines. From the holding/storage tank, the fortified oil is released through a spout and packed.

B. Mixing using a circulation system: In the circulation system, after the pre-blend is added to the oil in the main tank, it is allowed to completely re-circulate through pipelines for at least 30-40 minutes to ensure the uniform mixing of pre-blend with the oil. An outlet on the lower side of the main blending/circulation tank is present, through which fortified oil is sent to a holding/storage tank using stainless steel pipelines. From the holding/storage tank, the fortified oil is released through a spout and packed.

• Mixing the pre-blend with edible oil (Continuous Process)

In the continuous process, the pre-blend is filled in premix tanks. These tanks are equipped with agitators to keep a uniform distribution of vitamins in the fluid premix. A dosing pump that is synchronized with the flow rate of refined oil determines the amount of pre-blend added. Further blending of the pre-blend with the refined oil takes place at an appropriate point before storage to ensure the optimum distribution of the pre-blend through the refined oil.



Points to note :

- For a set-up comprised of the agitators, the cost may vary from INR 1 lakh- 10 lakhs, depending upon production quantity. For an industry which plans to expand with time, the agitator set-up works well.
- Depending upon the quantity of the oil production, the cost of circulation mixing set-up can vary from INR 5-20 lakhs. For an industry which is planned and designed for large scale production, circulation mixing works better.

Quality Assurance of Fortified Edible Oils

The purpose of quality assurance of the oil fortification process is to ensure that adequate quantities of vitamins A and D are added to the oil to meet the requirements of the standards prescribed by the FSSAI. The oil, once fortified, must be packed immediately as the vitamins are sensitive to light and oxygen. Final packaging of the oil must be done preferably in an opaque container to prevent the loss of vitamins during handling and transportation. Usually, two types of analyses are conducted for fortified edible oils.

A The first one is qualitative analysis, which is available only for analysing the presence/absence of Vitamin A in fortified oil samples. A qualitative analysis, which is also known as the 'Ring Test', is performed daily on samples drawn from every batch of production. It is an in-house test to determine the quality of fortification of the edible oils prior to packaging.

B The second is quantitative analysis in which the fortified oil samples are analyzed externally at NABL-accredited labs every 6 months to quantify the exact amount of Vitamin A and D present. Sampling of the fortified oil samples is also very important and needs to be done carefully. The process of sampling ensures quality control as it consists of representative samples from each batch of oil that is refined and fortified.

Points to note :

- Samples must always be collected from the packaging area (post refinement and fortification).
- The samples, sampling containers and the instruments used should be kept clean and free from possible contaminants.
- 0.5 litre retailer bottles must be utilized for the collection of samples and all sample information must be mentioned on the bottle (Name of mill, Date, Time, Batch number, Quantity, Signature of QA/ QC personnel).
- The sampling should be done for all the batches on a regular basis.
- The samples must be kept in opaque bottles, away from sunlight and possible contamination.
- There should be no air space in the collection bottles while collecting the samples. This may lead to oxidation, and eventual loss of vitamins.

Qualitative test/ Ring Test of Vitamin A in Fortified Edible Oil Samples by Rapid Carr-Price Reaction Method[7]

Principle

The method of detection is based upon the colour reaction of the Carr-Price solution, in which an unstable blue-coloured complex is observed when fortified edible oil is added to a solution of antimony trichloride in chloroform. The intensity of the developed blue colour is directly proportional to the concentration of Vitamin A in the edible oil sample. The colour reaction does not differentiate between retinol isomers or retinyl esters.

Requirements

1. Test tubes
2. Fortified oil Sample
3. Antimony trichloride solution (Prepared in an amber/brown coloured bottle)

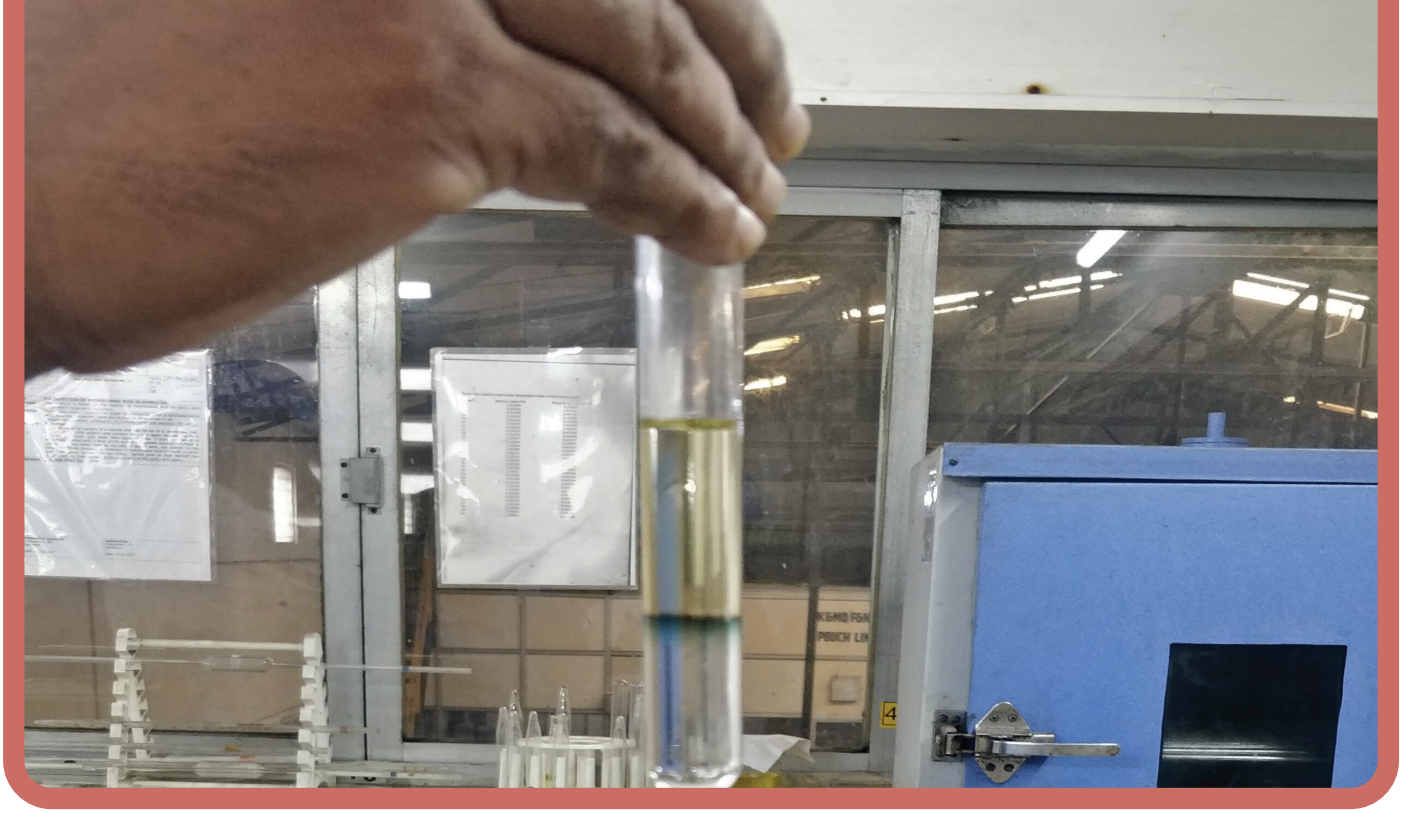
Preparation of antimony trichloride solution

1. 113.4 g of antimony trichloride is added to 400 ml of chloroform (not in distilled water).
2. After that, 5 g of anhydrous calcium chloride is added to it and the solution is filtered. The volume is made up to 500 ml with chloroform only.
3. The prepared solution is stored in an amber/brown coloured bottle.
4. Antimony trichloride solution must be prepared fresh every time before testing.

Procedure for Ring Test

1. A test tube is taken. 10 ml of antimony trichloride is poured into the test tube, followed by the slow addition of 15 ml of fortified oil sample.
2. The test tube with Antimony Trichloride solution should be slightly tilted (at about a 45-degree angle) when the fortified oil is slowly poured into it to get the green-blue colour ring at the interface. If kept straight, the addition of oil in the tube will give a very light violet blue or brown colour to the whole solution and not a clear ring.
3. The development of a blue colour at interface indicates the presence of Vitamin A in the oil sample. Care should be taken while taking observations as the ring appears only for few seconds.

[7]BIS 10633:1999 (Bureau of Indian Standards: Vanaspati)



Points to note :

- The qualitative test (Ring Test) to ascertain the presence of Vitamin A is to be conducted for every batch at the plant laboratory and findings recorded.
- The quantitative test provides the actual quantity of Vitamin A and D present in the fortified oil and needs to be performed once in 6 months. Levels of both Vitamin A and D should be within the range specified by the FSSAI.

Premix Handling and Management

A premix for edible oil fortification is an oil-based clear liquid. It is either odourless or has a faint odour. The premix used for edible oil fortification in India is an emulsion of Retinyl acetate or Retinyl palmitate and a plant source of Vitamin D. It should be added to oil at the rate of 20 g/metric ton.

Procure vitamin premixes only from FSSAI-notified premix suppliers. The list of FSSAI-notified suppliers is available on https://ffrc.fssai.gov.in/register.

- The Certificate of Analysis (COA) must be obtained from the supplier of the premix to ensure the right content of vitamins and acceptable organoleptic properties in the premix.
- Since Vitamin A is sensitive to light and oxygen, care should be taken that the premix is exposed to the minimum possible amount of light and oxygen, and is always stored in opaque bottles in cool, dry places.
- The premix must be assessed from time to time to check for its vitamin content and organoleptic properties and should only be used if it meets the specified requirements.
- All records of receipt, storage and dispatch of the premix must be kept up-to date and must be available at all times to the concerned person.
- The premix bottles should be stored at an ambient room temperature ranging from 23-32 degree Celsius.
- A pre-blend of the concentrated premix is made as per the regulations before it is added to the oil, depending upon the quantity of oil that is to be fortified.
- The shelf life of the premix must be considered while deciding on how much stock to maintain. The premix bottles must always be used in the first-in-first-out (FIFO) method.

Premix handling instructions

- The operator should use a mask to prevent inhalation of the active ingredients.
- The operator should wash hands and skin if exposed to the material. A colour-coded system should be followed to prevent accidental replacement of the premix with any other additives like antioxidants, stabilizers, etc.
- Opened bottles of premixes should be closed and stored away from light and heat.
- Any spilled material must not be used and should be disposed of.
- It is recommended to use gloves and long-sleeve shirts while handling the product to avoid potential allergic reactions.

Key Takeaways

Step 1: Pre-blend preparation

- Pre-heating of the premix is very important. It must not be skipped and should be done prior to pre-blend preparation.
- Premix should not be used directly. It is always advised to prepare a pre-blend before fortification.
- During manual preparation of pre-blend, precautions must be taken to ensure the uniform mixing of premix with oil. The solution must be stirred in a single direction only and the speed of stirring should be kept slow to avoid aeration of the oil.
- Rinsing of the premix is also very important to ensure there is no amount remaining in the bottle of the premix.

Step 2: Oil fortification

- If the pre-blend is prepared manually and needs to be transferred to the churning tank in manual mode only, a funnel should be used for pouring it in order to avoid spillage. The pre-blend should be transferred gradually to ensure uniform mixing in the storage tank.
- At the time of fortification, the tank should be filled at least two-thirds of its capacity.
- If the pre-blend is being transferred through stainless steel pipelines from the pre-blend tank to churning tank, the pipe should be dipped in the oil of the churning tank. This is to avoid oxidation of the oils.
- In either of the fortification processes i.e. batch process and continuous process, if the ring does not appear after 30-40 minutes of mixing, agitation or circulation must be continued for 10-15 minutes and samples need to be checked for ring formation.
- In the continuous mixing process, place the micro dozer 5-10 meters before the edible oil tank to ensure sufficient mixing.
- Basic Good Manufacturing Practices and Good Hygiene Practices should be followed during the fortification process.

Step 3: Sampling and qualitative analysis

- Samples should be drawn just before the packaging end line in triplicates at intervals of 5 minutes during the last 15 minutes of mixing pre-blend into the oil from every batch. These should be tested for the presence of the ring in order to ensure appropriate mixing of pre-blend into the oil.
- Light exposure of the oil samples needs to be avoided.
- Antimony trichloride must be prepared in a dark room and once prepared, must be stored in brown containers wrapped with aluminium foil.
- Test every batch of fortified oil before packaging using the qualitative test (Ring Test) for the presence of Vitamin A.
- A quantitative test should be done once every 6 months to know the exact quantity of added vitamins. Levels of both Vitamin A and D should be within the range specified by the FSSAI.

CONCLUSION

The FSSAI is considering making fortification of edible oil with vitamins A and D mandatory. Growing health awareness and regulatory initiatives taken up by the FSSAI are anticipated to drive the agenda of edible oil fortification across the country. Edible oil fortification involves simple blending and is easily achievable without the need for elaborate equipment. However, the important points mentioned above should be considered and the process of fortification should be carried out in a controlled manner to produce quality assured fortified edible oils.

Useful Resources:

1. Food Fortification Resource Centre (FFRC) – https://ffrc.fssai.gov.in/
2. Food Safety and Standards Authority of India (FSSAI) - www.fssai.gov.in

KHPT
IT Park, 5th Floor, 1-4, Rajajinagar Industrial Area,
Behind KSSIDC Admin office,
Rajajinagar, Bengaluru - 560 044
Ph: + 91 80 4040 0200, Fax: + 91 80 4040 0300
E: khptblr@khpt.org | W: www.khpt.org

GAIN INDIA COUNTRY OFFICE
D-2, Commercial Tower
The Edenpark Hotel (Qutab Hotel)
Qutab Institutional Area, Shaheed Jeet Singh Marg,
New Delhi - 110 016, India. Ph: + 91 (11) 4314 7575
E: bkaur@gainhealth.org | W: www.gainhealth.in