

AUGUST 2015 : VERSION 1

RICE FORTIFICATION TOOLKIT

TECHNICAL MANUAL



gain[®]
Global Alliance for
Improved Nutrition



PREFACE

Micronutrient malnutrition is a major impediment to socioeconomic development and contributes to a vicious circle of underdevelopment, to the detriment of already underprivileged groups. It has long-ranging effects on health, learning ability, and productivity. Micronutrient malnutrition leads to high social and public costs, reduced work capacity in populations due to high rates of illness and disability, and tragic loss of human potential. Overcoming micronutrient malnutrition is a precondition for ensuring rapid and appropriate development. Billions of people in the world today suffer from micronutrient malnutrition—substantially contributing to the global burden of disease, affecting the physical and cognitive development of young children, and dramatically reducing the work productivity of entire populations. Each year, anemia saps the energy and learning capacity of nearly two billion people, many due to iron deficiency.¹ Deficiencies of vitamin A and zinc adversely affect child health and survival, and are attributable for over 270,000 child deaths annually.² Lack of folic acid amongst expectant mothers during their first days of pregnancy causes more than 200,000 severe birth defects.³

Mass fortification of staple foods offers the opportunity to deliver key micronutrients to vulnerable populations at a low cost, without changing dietary habits. It is identified as one of the strategies used by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) to help decrease the incidence of nutrient deficiencies at the global level. It has been repeatedly cited as one of the best development returns on investment. According to the WHO/FAO, selection of an appropriate food vehicle to be fortified is governed by the following characteristics: the food should be commonly consumed on a regular basis by the majority of the population, centrally processed, and allow a micronutrient premix to be added relatively easily in a way to ensure even distribution in the product. Foods that are well-suited for fortification include cereals, oils, dairy products, and condiments including salt, sauces, and sugar.⁴

Amongst the cereals, rice is a staple food in many developing countries and is therefore considered to be an excellent potential fortification vehicle for populations that suffer from micronutrient deficiencies. For decades, commercial and nonprofit organizations have sought to develop appropriate technologies for fortifying rice. However, technical difficulties and high costs have hindered widespread distribution of fortified rice in public feeding programs around the world. The type of technology used to fortify rice kernels can have significant differences in cost, technical feasibility, and quality in terms of sensory characteristics and retention of nutrients during rinsing, washing and cooking.

¹ World Health Organization. <http://www.who.int/nutrition/topics/ida/en/> Accessed 29 December 2014.

² The Lancet (2013). Executive Summary of The Lancet Maternal and Child Nutrition Series. http://www.unicef.org/ethiopia/Lancet_2013_Nutrition_Series_Executive_Summary.pdf Accessed 29 December 2014.

³ <http://www.micronutrient.org/CMFiles/PubLib/Report-67-VMD-A-Global-Damage-Assessment-Report1-KSB-3242008-9634.pdf> Accessed 29 December 2014

⁴ WHO/FAO (2006). Guidelines on Food Fortification with Micronutrients, edited by Allen L, de Benoist B, Darz O, and Hurrell R. World Health Organization and Food and Agriculture Organization of the United Nations.

PREFACE (continued)

This toolkit describes in detail the process to blend fortified kernels with milled, non-fortified rice in order to produce fortified rice. It describes the equipment required, its integration with a typical rice milling facility, and important quality control (QC) aspects. It is relevant for the following professionals in the rice production industry:

1. General managers
2. Production managers
3. Production supervisors
4. Shift supervisors
5. Production engineers
6. Production foremen
7. Quality-control executives
8. Plant maintenance in-charge
9. Plant heads
10. Food safety officers
11. Utility managers

The Global Alliance for Improved Nutrition (GAIN) and PATH have developed this toolkit for building capacity of rice millers in upgrading their facilities for fortified rice production and ensuring quality. This toolkit serves as a consolidated manual to help any fortified rice manufacturing facility to carry out effective production of high-quality fortified rice. It also serves as a guidebook for training new employees on the fortified rice production process.

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INTRODUCTION

Rice is the staple food for an estimated 3 billion people, many of whom live in low-income countries with high prevalence of micronutrient deficiencies.⁵ In these areas, sufficient nutrient-rich foods do not always accompany rice. Rice is an affordable and accessible source of food, energy and protein, and is therefore crucial for nutrition security.⁶

Milled rice is low in micronutrients because its nutrient-rich outside layer is removed during typical rice milling and polishing operations. This makes the grain taste better and more visually appealing, but less nutritious. Fortification of rice can replace micronutrients lost during the rice-milling process and can help compensate for dietary insufficiencies. Fortifying a staple food such as rice has the added advantage of not requiring modifications to consumer purchasing or eating habits.

Rice fortification is very similar to wheat and maize flour fortification from a regulatory, public health and nutrition perspective. However, fortifying rice kernels is very different to fortifying wheat and maize flour. Recent technological developments have enabled a more widespread adoption of rice fortification as a cost-effective and feasible solution to address micronutrient deficiencies, supported by a growing number of governments, industry leaders, NGOs, UN Agencies, donors and other stakeholders. In many countries, rice consumers wash rice before cooking it. If the dusting method is used for fortification, where milled rice kernels are dusted with fortificant premix in powder form, this can result in loss of the added micronutrients. Fortifying rice through extrusion or coating technology represents a solution to this challenge. Fortified kernels resemble non-fortified rice grains in size and shape and do not break down during washing and cooking of rice. These kernels can be produced by one of several technologies including:⁷

- a) **Hot extrusion:** Dough made of rice flour, a premix, an optional emulsifier passes through a preconditioner where water and steam are added. The dough is then processed through a single or twin screw extruder and formed into grain-like structures that resemble rice kernels. This process involves relatively high temperatures (70–110°C) obtained by preconditioning and/or heat transfer through steam heated barrel jackets. It results in fully or partially pre-cooked simulated rice kernels that have a similar appearance (sheen and transparency) to regular rice kernels;
- b) **Cold extrusion:** A process similar to the one used for manufacturing pasta also produces rice-shaped simulated kernels by passing a dough made of rice flour, water, a fortificant premix, binders, moisture barrier agents through a simple pasta press. This technology does not utilise any additional thermal energy inputs other than the heat generated during the process itself, and is primarily a low temperature (below 70°C), which does not result in starch gelatinization but leads to grains that are uncooked, opaque and easier to differentiate from regular rice kernels. Thus the addition of pregelatinized starch and binders are needed to produce a cohesive product; and
- c) **Coating:** Combines the fortificant premix with ingredients such as waxes and gums. The mixture is sprayed to the rice on the surface of grain kernels in several layers to form the rice-premix. The micronutrients are sprayed onto the rice grain's surface. The coated rice kernels are blended with non-fortified rice in a ratio between 0.5 and 2%.

⁵ Muthayya S., Hall J., Bagriansky J., Sugimoto J., Gundry D., Matthias D., Prigge S., Hindle P., Moench-Pfanner R., Maberly G. Rice fortification: An emerging opportunity to contribute to the elimination of vitamin and mineral deficiency worldwide; Food and Nutrition Bulletin, 2012, vol. 33 no 4, 296-307

⁶ Ibid.

⁷ Steiger, G., Müller-Fischer, N., Cori, H. and Conde-Petit, B. (2014). Fortification of rice: technologies and nutrients. Annals of the New York Academy of Sciences, 1324: 29–39.

⁸ http://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp260013.pdf Accessed 29 December 2014.

INTRODUCTION (continued)

An important quality requirement for fortified kernels is their ability to protect micronutrients within the kernel – a feature that is particularly important where traditional preparation includes washing the rice prior to cooking. Fortified kernels should be a stable fortified grain that is intact and resistant to washing procedures before cooking. Nutrient combinations may be custom-designed to address specific dietary deficiencies in a targeted area.

The Rice fortification process detailed in this toolkit is a three step process:

1. Sourcing of fortified Rice kernels from a manufacturer
2. Dosing and blending Fortified Rice kernels with milled rice at a specific ratio (example, 1:200 or 1:100)
3. Bulk Storage and Packing

The manufacturing facility needed to fortify rice is essentially a rice mill with some line modification, or a new line (feeder and blender) at a warehouse. The production of fortified rice needs to follow all standard manufacturing, quality-control, and food-safety guidelines.⁸ These guidelines and good manufacturing practices (GMPs) are mandatory for any food-processing facility that is involved in manufacturing food products that are consumed by humans. The manufacturing and food safety⁶ practices must comply with all the statutory and regulatory guidelines of the country/state/region where the product is manufactured. Utmost care also needs to be taken in manufacturing and handling of fortified kernels because the finished product will be mixed with rice and distributed for consumption to consumers from different segments of the population.

This manual or toolkit covers the procedures and equipment needed for fortified rice production using blending techniques for key staff involved in the production. Specifically, it provides:

- An overview of the basic steps and equipment needed for fortified rice production in Chapter 1;
- An overview of various technologies for fortified kernel manufacturing to inform sourcing in Chapter 2;
- An overview of how to design the integration of blender and feeder in Chapter 3
- A detailed description of the selection of the right doser/ feeder for fortified rice production in Chapter 4
- A detailed description of the selection process for the right blending equipment for fortified rice production in Chapter 5;
- A brief description of good manufacturing practices and hazard analysis and critical control points (HACCP) for any rice milling facility in Chapter 6;
- Annexes with detailed plans and drawings.

To use this toolkit as a quick reference and guide for fortified rice production, see Chapter 5 for ready-to-use and concise guidelines. Other chapters will provide further details as needed.

Rice millers can contact regional or national rice miller associations for information on local fortified kernel producers. Additionally, for any general information, millers can communicate with PATH and GAIN. The contact information for these organizations is provided below.

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GLOSSARY

Administering authority: A certified organization that has the jurisdiction for certifying food safety and safety of manufacturing process. For example: a government department, local authority, etc.

Adulteration: Deliberate contamination of foods with materials of low quality.

Audit: A systematic examination involving professional judgment to determine whether food quality and safety activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Blending: Involves mixing milled, non-fortified rice with fortified kernels in ratios between 0.5 and 2% to produce fortified rice. Blending can be done at a rice miller, warehouse, or other location where rice is centrally processed. Small scale blending technology is also available.

Calibration: The demonstration that a particular instrument or device produces results within specified limits by comparison with those produced by a reference or traceable standard over an appropriate range of measurements.

Coating: Technology to make fortified kernels. Rice kernels are coated with a fortificant premix plus ingredients such as waxes and gums. The micronutrients are sprayed onto the rice grain's surface. The coated rice kernels are blended with non-fortified rice in a ratio between 0.5 and 2%.

Code of practice: It identifies the essential principles of food hygiene to ensure its safety for human consumption.

Codex Alimentarius: A collection of internationally recognised standards, codes of practice, guidelines, and other recommendations relating to foods, food production, and food safety.

Conditioning: Standardisation of the moisture content of flour and raw materials (RM) before extrusion.

Contamination: Incidence of any undesirable matter in the product so that it does not meet a standard or requirement determined by law, does not meet satisfactory food hygiene standards, or is unfit for human consumption.

Control measure: Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Corrective action: Any action to be taken when the results of monitoring at the critical control point (CCP) indicate a loss of control.

Critical control: Stages in a process where quality control (QC) can have a major effect on food quality.

Critical control point (CCP): A point in a step or procedure at which a control is to be applied to prevent or eliminate a hazard or reduce it to an acceptable level.

Critical limit: A value that separates acceptability from non-acceptability.

Cross-contamination: Contamination of a material or product by another material or product.

Decision tree: A series of questions that are applied to each step in the process in respect of an identified hazard to identify which steps are critical control points.

Detergent: A chemical that removes soils but does not sterilise equipment (see **Soils** below).

Disinfection: Use of approved chemical agents, physical methods, or both to reduce the number of micro-organisms to a level that will not lead to harmful contamination of the food, without adversely affecting the food.

Dusting: Technology to make fortified rice; polished milled rice kernels are dusted with a fortificant premix in powder form. This technology is only used in the United States and does not allow for washing pre-cooking or cooking in excess water since this will wash out the micronutrients.

GLOSSARY (continued)

Equilibrium relative humidity (ERH): The moisture content at which a food does not gain or lose weight and is stable during storage.

Essential micronutrient: Refers to any micronutrient (vitamin or mineral), which is needed for normal growth and development by the body in miniscule amounts throughout the life cycle. Micronutrients are normally consumed as part of a healthy and diverse diet. They either cannot be synthesised in adequate amounts by the body at all, or cannot be synthesised in amounts adequate for good health and thus must be obtained from a dietary source.

Establishment: Any structure(s) or area(s) in which food is handled and the environment is under the control of the same management.

Extrusion: technology to make fortified kernels. Rice-shaped simulated kernels are produced by passing rice flour dough, containing a fortificant premix, through an extruder. The extruded kernels, which are made to resemble rice grains, are then blended into non-fortified rice in a ratio between 0.5 and 2%, similar to the coating technology. Extrusion allows for the use of broken rice kernels as an input, and may be carried out under hot, warm, or cold temperatures, which influences the appearance of the final fortified kernel.

Fill-weight: The amount of food placed into a container or package and written on the label (also net weight).

Flow diagram: A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular food item.

Food additive: Any substance not normally consumed as a food by itself and not normally used as a typical ingredient of the food, whether or not it has nutritive value, the intentional addition of which to food for a technological (including organoleptic) purpose in the manufacture, processing, preparation, treatment, packing, packaging, transport, or holding of such food results, or may be reasonably expected to result (directly or indirectly), in it or its by-products becoming a component of or otherwise affecting the characteristics of such foods. The term does not include contaminants or substances added to food for maintaining or improving nutritional qualities (Codex Alimentarius).

Food chain: All the stages through which food is handled, from primary production to processing, manufacturing, distribution, and retail to the point of consumption.

Food handler: A person who, in the course of his or her normal duties, comes into contact with food not planned for his or her own use.

Food handling: Any process in the growing, harvesting, preparation, processing, packaging, storage, transportation, distribution, and sale of food.

Food hygiene: All conditions and actions necessary to ensure the safety, soundness, and wholesomeness of food at all stages, from its production or manufacture through to its final consumption.

Food premises: A building, structure, stall, or other similar structure including a caravan, vehicle, stand, or place used for or in association with the handling of food.

Food safety: The guarantee that a particular food product will not cause injury to the consumer when it is prepared and / or eaten according to its proposed use.

Food spoilage: Any microbiological food deterioration.

Food suitability: The guarantee that a food is suitable for human consumption according to its intended use.

Fortificant: Selected essential micronutrient in a particular form to fortify selected food (e.g. rice, flour, salt).

Fortificant premix: Blend that contains several fortificants.

GLOSSARY (continued)

Fortification: Practice of deliberately increasing the content of essential micronutrient(s), i.e. vitamins and minerals, in a food, so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health. The essential micronutrients are added to make the food more nutritious post-harvesting. Fortification is synonymous with enrichment, and is irrespective of whether the nutrients were originally in the food before processing or not.

Fortified kernels: Fortified rice-shaped kernels containing the fortificant premix (extrusion) or whole rice kernels coated with a fortificant premix (coating). Fortified kernels are blended with non-fortified rice in a ratio between 0.5 and 2% to produce fortified rice.

Fortified rice: Rice fortified with fortificant premix by dusting or non-fortified rice combined with the fortified kernels in a 0.5 – 2% ratio. Typically fortified kernels are blended with non-fortified rice in a 1:100 (1%) ratio.

Good manufacturing practice (GMP): The combination of manufacturing and quality measures aimed at ensuring that a product is always manufactured to its specification.

General manager (GM): Person responsible for the entire manufacturing process of fortified kernels and fortified rice in the plant from selection and receipt of raw material to the final dispatch of the packaged grains.

Hazard analysis and critical control point (HACCP): A system which identifies, evaluates, and controls hazards which are significant for food safety.

HACCP plan: A written document accepted by the regulatory authority that delineates the formal procedures for following the HACCP system that identifies, evaluates, and controls hazards which are significant to food safety. It is based upon the Codex Alimentarius principles of HACCP and includes a generic hazard analysis for the process that results in a list of recognised hazards, which are then translated into a series of critical points and prerequisite programmes to support the wholesomeness of the safety system.

HACCP study: The process of applying the stages used to design the HACCP system.

Hazard: A biological, chemical, or physical agent in the food chain with the potential to cause an adverse health effect for animals or consumers.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence in all steps in the establishment or production operation, in accordance with the appropriate HACCP principles, to decide which are significant for food safety and therefore should be addressed in the HACCP plan and to elaborate the specific CCP and critical limit for each hazard as defined by Codex Alimentarius.

Hazard characterisation: The qualitative assessment of the nature of any adverse result associated with any biological, chemical, or physical agents, or a combination of these that might be present in food.

High-risk foods: Foods that are capable of transmitting food-poisoning micro-organisms to consumers.

Incoming material: A general term used to denote raw materials (starting materials, reagents, and solvents), process aids, intermediates, and packaging and labelling materials.

Intermediate: Any product that has not yet been labelled as a final product, intended to be first placed on the market as a food additive.

GLOSSARY (continued)

Internal traceability: Traceability from inputs to outputs within an individual food production or processing site.

Lot: A specific quantity of material produced in a process or series of processes so that it is expected to be homogeneous within specified limits. In the case of continuous production, a lot may correspond to a defined fortified rice action of the production. A lot size may be defined either by a fixed quantity or the amount produced in a fixed time interval.

Lot number: A combination of numbers, letters and/or symbols which identifies a lot and from which the production and distribution history can be determined.

Manufacturing process: All operations of receipt of materials, production, packaging, repackaging, labelling, re-labelling, QC, release, storage, and distribution of food additives and premixes and the related controls.

Micro-organisms: Tiny forms of life, including molds, bacteria, and yeasts, which are invisible until they are present in large numbers.

Milled rice: polished rice is the regular-milled white rice. Hull, bran layer and germ have been removed, and so have most of the vitamins.

Minimum weight: All packages have a fill-weight equal to system or greater than that shown on the label.

Monitor: The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Net weight: The amount of food filled into a container.

Non-conformity: Non-fulfilment of a particular requirement.

Non-fortified rice: Milled rice without fortification

Operator: Any unit of producing or manufacturing food premixes prepared from additives and any person, other than the manufacturer or the person producing for the exclusive requirements of his holding, who holds additives or premixes prepared from additives.

Packaging material: Any containers such as cans, bottles, cartons, boxes, cases and sacks, or wrapping and covering material, such as foil, film, metal, paper, wax-paper, plastics, and cloth.

Pest: Any animal competent of contaminating food directly or indirectly.

Potable water: Drinkable water that will not cause illness.

Premixes: Mixtures of food additives or mixtures of one or more food additives with food materials or water used as carriers, not intended for direct consumption by humans.

Prerequisite program: Prerequisite programmers such as GAP, GMP, and good hygiene practices (GHP) must be working effectively within a commodity system before HACCP is applied. If these prerequisite programmers are not functioning effectively, then the introduction of HACCP will be complicated, resulting in a cumbersome, over-documented system.

Pulverising: The process of reducing the size of material into fine particles using a mechanical device.

Quality assurance (QA): Refers to the implementation of planned and systematic activities necessary to ensure that products or services meet quality standards. The performance of quality assurance can be expressed numerically as the results of quality control exercises. For the purposes of this manual, QA refers to a management system which controls each stage of food production from raw material harvest to final consumption.

Quality characteristics of a food: A set of descriptions that identifies the specific quality features.

GLOSSARY (continued)

Quality control (QC): Refers to the techniques, checks, and assessments used to document compliance and uniformity of the product with established technical standards, through the use of objective and measurable indicators.

Raw material: All materials which are in the final product.

Reworking: Any appropriate manipulation steps taken when the product does not comply with specifications and when it is possible to follow corrective actions. The result of these actions must ensure a food additive or premix conforms to specifications.

Rice flour: A form of flour made from finely milled rice. Rice flour may be made from either white rice or brown rice. To make the flour, the husk of rice or paddy is removed and raw rice is obtained, which is then ground to flour.

Shelf life: The time that a processed food can be stored before changes in color, flavor, texture, or the numbers of micro-organisms make it unacceptable.

Soils: Any material that contaminates equipment (e.g., grease, scale, burned food, or other food residues).

Standard operating procedures (SOP): Any manufacturing practice ruled by commonly

accepted operational practices for the particular process.

Specification: A list of tests, references to analytical procedures, and appropriate acceptance criteria that are numerical limits, ranges or other criteria for the test described. It establishes the set of criteria to which a material should conform to be considered acceptable for its intended use. 'Compliance to specification' means that the material, when tested according to the listed analytical procedures, meets the listed acceptance criteria.

Sanitation standard operating procedures (SSOP): To conduct cleaning and sanitation procedures as established by the GMP.

Total quality management (TQM): A management approach that is centered on quality, based on the participation of all members of the association and aimed at long-term achievement through customer satisfaction and through benefits to all members of the organization and of society.

Toxic: Harmful to human, animal, or plant health.

Traceability: Ability to follow the movement of a food product through the food supply chain and within an individual company.

Tracking: Ability to follow the path of a

specified unit and/or lot of trade items downstream through the supply chain as it moves between trading partners.

Validation: Obtaining evidence that the elements of the HACCP plan are effective.

Verification: The application of methods, procedures, tests, and other evaluations, in addition to monitoring, to determine compliance with the HACCP plan.

Waste materials: Unused materials, or used materials subsequently disposed of, including cleaning materials, disinfectants, and hazardous materials.

ACRONYMS

CAR: Corrective Action Request

CCP: Critical Control Point

CDC: Centres for Disease Control and Prevention

CIP: Cleaning in Place

EHS: Environment Health Safety

ERH: Equilibrium Relative Humidity

FePP: Ferric Pyrophosphate

FG: Finished Goods

FSSAI: Food Safety and Standards Authority of India

GHP: Good Hygiene Practices

GM: General Manager

GMP: Good Manufacturing Practice

Green FBG: Green Ferric Bisglycinate

HACCP: Hazard Analysis and Critical Control Point

HOD: Head of the Department

MSDS: Material Safety Data Sheet

NABL: National Accreditation Board for Testing and Calibration Laboratories

PM: Packaging Material

PPE: Personal Protective Equipment

QA: Quality Assurance

QC: Quality Control

QMS: Quality Management System

RO: Reverse Osmosis

RPM: Revolutions per Minute

SOP: Standard Operating Procedures

SSOP: Sanitary Standard Operating Procedures

STPP: Sodium Tripolyphosphate

TDS: Total Dissolved Solids

TQM: Total Quality Management

µm: Micrometre

WHO: World Health Organization

CHAPTER 1:

OVERVIEW OF THE MANUFACTURING PROCESS FOR FORTIFIED RICE

CHAPTER 1: OVERVIEW OF THE MANUFACTURING PROCESS FOR FORTIFIED RICE

This chapter provides an overview of the steps required for production of fortified rice by the rice miller. The objective of this chapter is to familiarize the plant operator with basics of effective operations for blending fortified kernels with polished rice and to ensure consistent good quality of fortified rice.

WHAT IS FORTIFIED RICE?

Fortified rice is a mixture of fortified kernels and non-fortified rice (also called traditional or polished rice) in a specific ratio (often 1:100) as per the regulatory and market requirements. The blending process is relatively simple and has three steps (Figure 1.1):

1. Metering the fortified kernels into a regular rice using a feeder/doser;
2. Blending the mixture for some time; and
3. Storing and packaging.

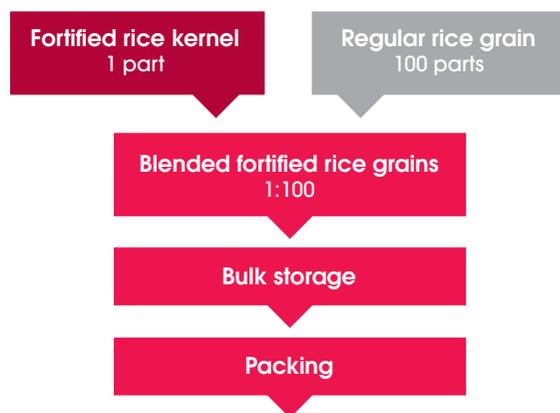


Figure 1.1. Basic steps for fortified rice production

METERING OF FORTIFIED KERNELS

Fortified kernels obtained from the production process described in Chapter 1 are blended with regular rice using a method which gives the highest uniformity. A doser or feeder is employed using the blender to meter fortified kernels in the right ratio. In order to ensure uniformity of fortified kernels in the final fortified rice, the doser needs to be calibrated as per the desired ratio of the fortified kernels to non-fortified kernels. A vibratory feeder is one example of such a dosing system (Figure 1.2), although other kinds of dosers can also be employed as described in a later section.



Figure 1.2. Vibratory feeder with frequency controller

CHAPTER 1: OVERVIEW OF THE MANUFACTURING PROCESS FOR FORTIFIED RICE (continued)

BLENDING OF FORTIFIED RICE (Chapter 5)

A blender is employed downstream of the doser. The blender and doser combination allows uniform blending of fortified kernels and traditional rice in the desired ratio (such as 1:100) in fortified rice.

Blending can be done using various types of equipment, as described in a later section. An example of a blender is the Forberg blender, used as standalone machine for batch blending (Figure 1.4). Existing equipment in a rice mill can also be adapted for the purpose of blending. An example of such adaptation would be to use existing milling graders or length-grading cylinders in a traditional rice-milling system as a continuous blender. This is described in greater detail in Chapter 5.

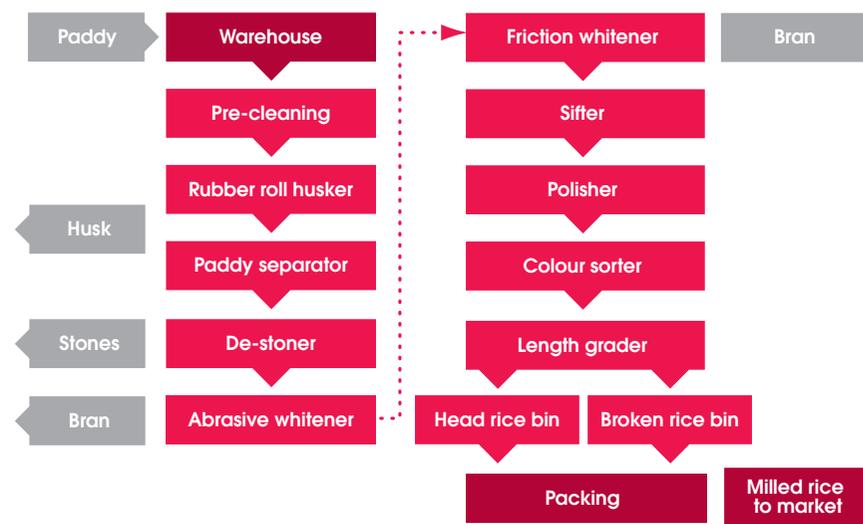
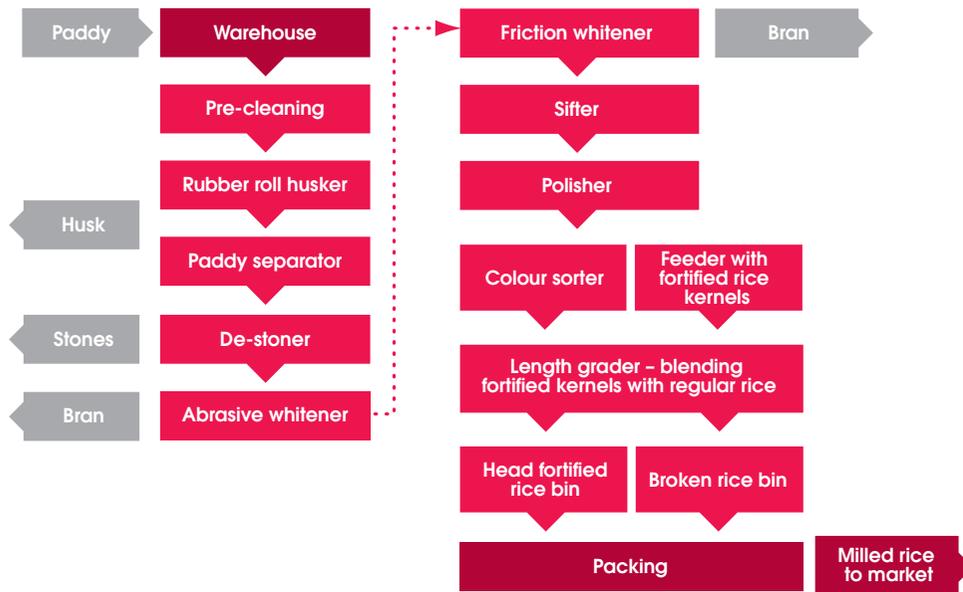


Figure 1.3. Typical flow chart of rice mill – unfortified

CHAPTER 1: OVERVIEW OF THE MANUFACTURING PROCESS FOR FORTIFIED RICE (continued)



STORING AND PACKAGING FORTIFIED RICE

After blending, fortified rice is often stored in bulk and subsequently packaged in bags as per the standard operating procedure of the rice mill. No special modifications need to be made to the storage and packaging SOPs employed for regular rice. Some of the general steps that are taken for packing may include ensuring correct type of packing material – including the right bag size – is used as per customer requirement; batch coding procedure and recording of quantities for each batch; printing as per the requirements; weighing of bags at random to check that weight is correct; verifying that sealing of inner packing material and stitching of outer bag are done properly; and ensuring critical control points (CCP) are in place for post-packaging (e.g. metal detector) and SOPs are followed for final storage of bags.

Figure 1.4. A potential flow chart of fortified rice mill – transforming length grader into blender

CHAPTER 2:

SOURCING OF FORTIFIED KERNELS

CHAPTER 2: SOURCING OF FORTIFIED KERNELS

This chapter provides an overview of the process to be followed for manufacturing fortified kernels. The objective of this chapter is to familiarize the production staff with the basic steps involved in the manufacturing of fortified kernels.

WHAT ARE FORTIFIED KERNELS?

Fortified kernels are rice kernels that are highly fortified (x100 to x200) with the desired vitamin and mineral fortificant premix by applying a coating to grains or by reconstitution of grains from a mixture of rice flour and fortificant premix using extrusion. Fortified kernels are typically blended with polished rice in a ratio of 1:100 or 1:200 (depending on the concentration of fortificant) by the rice miller to produce fortified rice ready for consumption.

TYPES OF TECHNOLOGIES AVAILABLE FOR PRODUCING FORTIFIED KERNELS

Different technologies with varying degrees of sophistication are available for producing fortified kernels. The three major fortified kernel production technologies are: hot extrusion, cold extrusion, and coating. These are described in detail below.

Hot extrusion

This extrusion method involves use of equipment such as a hammer mill for rice flour production, mixers, single or twin screw extruders (often fitted with a steam and water preconditioning system), and dryers. The process uses relatively high temperature (70-110°C) in combination with low shear, resulting in a product with very similar properties (sheen, transparency, consistency and flavor) to those of non-fortified rice grains. The rice flour (which may be obtained from broken rice kernels or poor quality rice) is mixed with the fortificant

premix, water, binding agents and emulsifiers before passing through the extruder. The dough moves through the extruder via one or more screws, experiencing increased pressure, shear, and heat during the process. Attachments at the end of the extruder shape and cut the paste into grain-like structures resembling rice kernels. The higher temperatures are obtained by steam preconditioning prior to extrusion and/ or heat transfer through heated barrel jackets, and leads to fully or partially precooked simulated rice kernels.

Cold extrusion

This technology is similar to the one described above, except it utilises a simple forming extruder also called a pasta press, which does not involve any additional thermal energy input other than the heat generated during the process itself. It is primarily a low temperature (below 70°C) and low shear forming process resulting in grains that are uncooked, opaque and easier to differentiate from regular rice kernels. The process is similar to the one used for manufacturing pastas.

Antioxidants may be added as part of the ingredients of the synthetic rice kernels to improve the stability of the vitamins. The process involves combining a fortificant premix with rice flour dough, extruding, shaping and cutting into rice-shaped grains, and drying. The resultant product resembles non-fortified rice kernels in size and shape, although it has a slightly softer consistency and is more opaque than non-fortified rice kernels.

CHAPTER 2: SOURCING OF FORTIFIED KERNELS (continued)

The equipment includes a hammer mill, pasta press, and drying equipment such as perforated belt dryer and/or large tray dryers for pre-drying and final drying. The rice flour is mixed with the fortificant premix, and water is added to adjust the overall moisture to about 35% (wet basis) in batch mixers. The wet flour is transferred to the pasta press where it is reformed into rice-like grains using a specially designed screw and dye, and a continuously acting rotational knife. The re-fabricated fortified kernels are then dried. Drying procedures and equipment vary depending on the manufacturer. As one example, a typical drying steps may include pre-drying in a perforated belt (several passes) continuous drying system using air at 70°C for 2 to 2.5 hours, and final drying by stacking the partially dried fortified kernels in trays and placing them in conditioning chambers for eight hours for final drying at 60–70°C. The dried fortified kernels are then bagged and stored under appropriate temperature and humidity conditions.

Coating technology

In the coating method, ingredients such as waxes and gums are combined with the fortificant premix to create a liquid which is sprayed to the rice in several layers on the surface of grain kernels to form the rice-premix of fortified kernels. The fortified kernels are then blended with retail rice for fortification. The waxes and gums enable the micronutrients to stick to the rice kernel, thus reducing losses when the grains are washed before cooking, which is a common practice in developing countries. The final product is rice covered by a waxy layer; the colour depends on the fortificants that are added. There are several variations of this method as described below:

a) Ethyl cellulose based adhesive coating: Fortified kernels are prepared in batches using a horizontal rotary drum mixer. The mixer consists of a stainless steel rotating drum supported by two pillow block bearings. The bearings are supported by a steel frame that sits on a steel support base. The mixer drum has up to 12 spray nozzles for delivering an adhesive coating (ethyl cellulose) and pharmaceutical glaze to the milled rice, and rotates at about 3 rpm to achieve a uniform coating in 2 to 3 minutes. The mixer is equipped with a packager that automatically fills the coated grain premix into 50 lb. bags.

b) Microperforations based coating: The micronutrient premix is embedded in microperforations specially created on the rice kernel surface using a proprietary technology.

c) Wax based coating: The coating process uses a special mixture, which is made of palm oil-based wax, gums, and an emulsifier. Two solutions are prepared, one containing the wax mixture and the other containing wax mixture and micronutrient premix in a 1:1 ratio, by dissolving in water at 85°C. A batch coating drum is then used to apply these solutions onto the surface of rice grains in a multi-step process resulting in several coating layers, with each step involving a coating of the wax solution followed by a coating of the wax-premix solution. The coated rice is simultaneously dried in the drum using hot air. The final moisture content of the coated rice is 10% (wet basis). The batch process takes about an hour to complete.

CHAPTER 2: SOURCING OF FORTIFIED KERNELS (continued)

d) Agar based coating: This coating method employs agar instead of waxes. This method however is not very suitable for rice fortification as the coating layer is easily separated from the rice grain.

SOURCING OF FORTIFIED KERNELS

A list of potential supplier is available on PATH website and also in Annex 9.

The cost, appearance and quality of fortified kernels produced by above mentioned technologies varies. To ensure consumer acceptance of final product it is important to choose fortified kernels close in appearance (transparency, shine) to the milled rice it is blended with. This would avoid consumer being able to spot any changes and avoid bias.

Of the three methods, coating is the least expensive while hot extrusion is the most expensive.⁹ Based on theoretical cost comparisons, the final cost of fortified kernels would be more or less the same regardless of the number and type of micronutrients added. The total cost of the fortified rice produced by any method depends on factors not associated with the fortificant premix such as purchasing the rice grains, manufacturing the rice flour, and investing in equipment and facilities.

⁹ Alavi, S., Bugusu, B., Cramer, G., Dary, O., Lee, T.C., Martin, L., McEntire, J., and Wallis, E. 2008. Rice fortification in developing countries: A critical review of the technical and economic feasibility. Agency for Educational Development. http://pdf.usaid.gov/pdf_docs/pnaeb101.pdf Accessed December 14, 2014.

CHAPTER 3: DESIGNING THE INTEGRATION OF BLENDER AND FEEDER

CHAPTER 3: DESIGNING THE INTEGRATION OF BLENDER AND FEEDER

The production of fortified rice by blending of fortified kernels with regular rice can be done using one of the following set-ups depending on the current production constraints:

1. **Batch blending (suitable for warehouse blending or small to medium size rice mills)**
2. **Continuous blending (suitable for medium to large-scale rice mills)**

BATCH BLENDING

Best practice for obtaining a uniform blending of fortified rice is to use a combination of vibratory doser with Forberg blender. This combination of blender and doser is suitable for small to medium scale rice mill/warehouse set-ups. The Forberg blender has a very small blending cycle of 3 minutes per batch, achieving the required blending homogeneity (below 15% CoV; 3.7–13.6% CoV as tested). The integration of the vibratory feeder with the Forberg blender is described below. **Note it is possible to opt for other combinations of dosing systems and blenders and tailor the integration framework according to suitability to the particular operation.**

INTEGRATION OF A BATCH BLENDING SYSTEM (AN EXAMPLE)

An example framework to integrate the blender and feeder and to regulate the opening and closing of the gates controlling the flow of rice and fortified kernels is described below. The entire system is connected to a control panel which runs using a computer program. The broad design is given below and also provided as drawings in the Annexes.

The major components used for developing the framework are given below and are also illustrated in Figure 5.1.

- **400 Kg hopper:** To store and feed the traditional rice into the blender
- **Load cells for 400 Kg hopper:** To weigh the required amount of traditional rice
- **50 Kg hopper:** To feed the calculated amount of fortified rice kernel into the 10 Kg hopper
- **10 Kg hopper:** To feed the fortified rice kernel into the blender
- **Load cells:** Weighing sensors for fortified kernels connected to the PLC panel
- **Open and close gates for hoppers:** To control the flow of the rice and fortified kernels as required
- **Cylinders for gates:** To close and open the gates of hopper controlling the flow of rice and fortified kernels
- **Compressor for cylinders:** Builds hydraulic pressure which helps in opening and closing of the gates
- **Frames for hoppers:** The entire frame is built with mild steel
- **PLC:** The programmable logic controller to control the whole system and make it work automatically

The framework was built rugged to withstand the vibrations of the blender. The framework, after being installed at rice mill, would appear as in the pictures below.

CHAPTER 3: DESIGNING THE INTEGRATION OF BLENDER AND FEEDER (continued)



Figure 3.1. Framework for integration of vibratory feeder with Forberg blender

OPERATIONAL AMENDMENTS AT THE RICE MILL

Amendments or changes will need to be carried out in the process flow and operations of the rice mill to allow blending of fortified kernels. The operational flow at a typical rice milling operation might be as follows (also shown in Figure 3.2):

1. Paddy is dumped in the intake pit feeding the pre-cleaner
2. Pre-cleaned paddy moves to the rubber roll husker
3. Mixture of brown rice and unhusked paddy moves to the separator
4. Unhusked paddy is separated and returned to the rubber roll husker
5. Brown rice moves to the de-stoner
6. De-stoned, brown rice moves to the 1st stage (abrasive) whitener
7. Partially milled rice moves to the 2nd stage (friction) whitener
8. Milled rice moves to the sifter
9. Milled rice moves to the polisher
10. Polished rice, will move to color sorter
11. Discoloured grain will be separated by color sorter
12. Milled rice moves to length grader
13. Broken rice will be separated from the head rice
14. Head rice moves to head rice bin
15. Broken rice moves to broken rice bin
16. Head rice moves to packing section
17. Bagged rice moves to the market

CHAPTER 3: DESIGNING THE INTEGRATION OF BLENDER AND FEEDER (continued)

This typical process will need to be modified to effectively use the fortified kernel blender in the rice milling environment. The following example illustrates incorporation of the Forberg blender (batch blender) to produce fortified rice in a typical rice milling operation. In every rice mill, the milled rice will be stored in large 'Silos'. From silos the rice will be carried to the packing machinery using suitable elevators. Consider if there are 2 silos (S1 and S2), the milled rice will go directly into S1. The milled rice from S1 will be transferred to the blender using the elevator, batch-by-batch. After blending, the fortified rice will go to S2. Once S2 has significant quantity of fortified rice, it will be transferred to the packing machine to be packed and stored in the warehouse. The same process has been explained in a pictorial form below (Figure 3.2). In this way, with minimum amendments to the existing milling system, we can effectively use low-cost blenders for effective blending operations. To attain maximum efficiency, the blending capacity should be equal to the milling capacity.

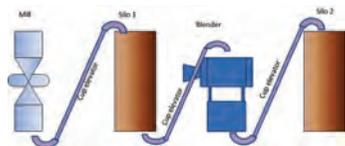


Figure 3.2. Rice flow sequence for fortified rice production

CONTINUOUS BLENDING

For large scale rice milling operations, the best option is continuous blending and using existing milling/ rice graders in the traditional rice mill as blending equipment in combination with a vibratory dosing unit. This method is a continuous feeding method and can help to increase the productivity while maintaining the uniformity of the blend (below 15% CoV; 9.1-12.4% CoV as tested). It is important to calibrate the vibratory doser/feeder as per the desired quantity of the fortified kernels in the final fortified rice (Figure 3.3). To obtain the uniform blending, the vibratory feeder should discharge the fortified grain to match the flow of traditional rice in the rice grading cylinder. **Note it is possible to opt for whatever combination of dosing system and continuous blender and also tailor the integration framework according to suitability to the particular operation.**



Figure 3.3. Calibration of dosing equipment is very important for continuous blending. See the Annexes for an example calibration record keeping format

CHAPTER 3: DESIGNING THE INTEGRATION OF BLENDER AND FEEDER (continued)

INTEGRATION OF A CONTINUOUS BLENDING SYSTEM (AN EXAMPLE)

The outlet of a vibratory feeder for fortified kernels is attached to one inlet of the bucket elevator. Fortified kernels are added by the vibratory feeder and mixed with regular rice coming to the bucket elevator from the colour sorter. The mix is conveyed by the bucket elevator to the length grader. This set up is illustrated in Figure 3.4. The length grader, by virtue of its grading mechanism, churns the mix along with separating the broken grains from the mix. This churning helps in the uniform distribution of fortified kernels in the final fortified rice obtained at the rice outlet head of the length grader. During the process of blending, the rice flow in both the inlets should be maintained constantly to avoid any issue of homogeneity in the blend. The vibratory feeder should be started as soon as there is regular rice flow in the other inlet of the bucket elevator.

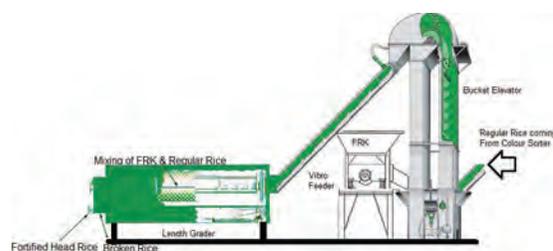


Figure 3.4. Integration of dosing and cylindrical rice grader for continuous blending of regular rice and fortified kernels to produce fortified rice

SUMMARY

Chapter 3 provides a summary of guidelines for fortified rice production and equipment. To use this toolkit as a quick reference and guide for fortified rice production, ready-to-use and concise guidelines are found in this chapter. For a small scale rice milling operation and/or in a situation where blending for fortified production would be done in a warehouse due to limited space and resources, the combination of a vibratory feeder and a batch Forberg fluidised blender would be appropriate. For a medium to large scale rice mill, a continuous blending operation for fortified rice production would be better suited in order to match the high throughput. In this situation, the combination of a vibratory feeder and a continuous blender such as an existing rice length grader would be appropriate. **Note that it is possible to opt for whatever combination of dosing/ feeder system and continuous or batch blending equipment that suits a particular operation, and also to tailor the overall integration of the fortified rice production process based on detailed information provided in Chapters 2, 4 and 5.**

CHAPTER 3: BLENDING EQUIPMENT SELECTION (continued)

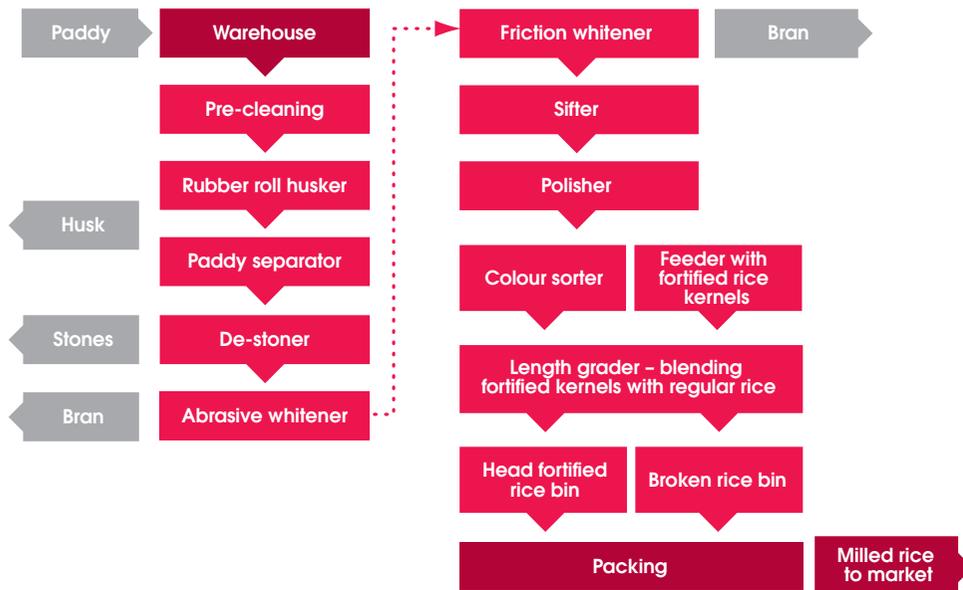


Figure 3.5. Typical flow chart of fortified rice mill – transforming length grader into blender

KEY POINTS TO REMEMBER (SOME ARE SPECIFIC TO THE USE OF A RICE GRADING CYLINDER AS A BLENDER):

1. Pre-calibration of the vibratory feeder needs to be done before application.
2. Uniformity of the blend needs to be assessed regularly during blending operation.
3. Flow of regular rice should also be maintained to get uniformly distributed fortified rice.
4. Blender needs to be attached with solid base to avoid disturbance in calibration.
5. Both the inlets of the bucket elevator should never run empty.
6. Starting and stopping of the vibratory feeder should be synchronized with regular rice flow in blender; interlocking the vibratory feeder with the elevator is a good option.

CHAPTER 4: DOSING EQUIPMENT SELECTION

CHAPTER 4: DOSING EQUIPMENT SELECTION

There are several types of dosing equipment/feeders available that can be used for metering fortified kernels. Two common types are described below:

- a. Vibratory feeder
- b. Conveyor feeder

VIBRATORY FEEDER

A vibratory feeder is an instrument that uses vibration and gravity to move and deliver the material to another system, such as the blender. Gravity is used to determine the direction, either straight down or down and to a side, and then vibration is used to move the material.



(a)

(b)

Figure 4.1. Examples of vibratory feeders with frequency controller

An example of a vibratory feeder that can be used for fortified rice production in a rice mill is provided below.

Description: 'VIBRANT' Electromagnetic vibratory feeder with vibratory feeder drive unit, feeder tray and feeder controller.

Specifications:	1. Model	: VVF - 2
	2. Trough size	: 100 x 450 mm
	3. MOC contact parts	: SS-304
	4. Capacity	: 0-500 Kg/Hr of powder/grain
	5. Powder/grain density	: 1000 Kg/cu mtr
	6. Controller	: Thyristorised for controlling the feed rate

CHAPTER 4: DOSING EQUIPMENT SELECTION (continued)

CONVEYOR FEEDER

A conveyor feeder uses a belt conveying system to deliver material from a hopper to the downstream equipment. Typically, a load sensor under the belt continuously measures the weight of the product over a defined length of belt in order to meter the material.



Figure 4.2. Conveyor belt feeders (Source: <http://www.cccomponents.com.au>).

An example of a conveyor feeder that can be used for fortified rice production in a rice mill is provided below.

Description: Belt conveyor with geared motor

Specifications:

1. Conveyor material	: Food grade plastic
2. Capacity	: 300 Kg/hour
3. Length of the conveyor	: 600 mm
4. Width of the conveyor	: 200 mm
5. Capacity	: 1 HP

COMPARISON OF DOSING EQUIPMENT

Trial tests were conducted with the above mentioned dosing systems or feeders in combination with the Forberg blender.

The vibratory feeder provided good results at the following setting: 3 minutes of blending time at 50 rpm blending speed. The Coefficient of Variation of fortified kernels in fortified rice samples ranged from 3.7–13.6%, and was within the specifications of below 15%. The conveyor feeder trial were inconclusive since difficulties were encountered in controlling flow and maintaining accuracy in feeding.

Note these trials tests are mostly indicative and based on equipment specifications above. A screw feeder has also been tested but it increases the amount of broken kernels

For engineering design of vibratory, screw and conveyor feeders see the Annexes.

CHAPTER 5:

BLENDING EQUIPMENT SELECTION

CHAPTER 5: BLENDING EQUIPMENT SELECTION

When selecting the blenders, available blenders should be evaluated based on several criteria, including existing set-up of the operations, current throughput of the line where the fortification needs to be integrated:

1. **Choice of continuous/batch blending depends on the ease to integrate the equipment to current settings and choice of operations**
2. **Cost of equipment and its operational cost;**
3. **Operational ease**
4. **Effectiveness of blend (homogeneity achieved), precision mixing; time of blending**
5. **Gentle mixing (low broken percentage);**
6. **Suitability to grain blending (potential damage to kernel or product loss)**
7. **Maintenance requirements (low/high)**

CHOICE OF BLENDING

The choice of continuous and batch blending depends on several factors. Continuous blending requires less handling operations than batch blending and can handle larger volume as required in a conventional rice milling environment. Often the choice of the type of blender is centered on those blenders that can be integrated into continuous milling environment (Table 5.1). A continuous mixing system operates simultaneously at three stages:

1. material proportioning or metering,
2. blending, and
3. discharge.

Batch versus continuous mixing should be carefully evaluated in the context of the capacity, economics and technological feasibility by each fortified rice manufacturer or rice miller. In some cases, batch mixing might be more advantageous for reasons mentioned below:

- More flexibility in the process and possibly greater blending homogeneity at various blending time periods;
- Ability to control feeder and blender individually to attain various speeds and time periods; and
- Batch mixing can handle smaller volumes and can reduce cost for a lower capacity operation.

CHAPTER 5: BLENDING EQUIPMENT SELECTION (continued)

Table 5.1. Comparison of batch mixing and continuous mixing operations

PROPERTY	BATCH MIXING	CONTINUOUS MIXING
Capital cost and Operating Cost	Depends on the size of the blender and expected throughput	
Mixer ancillary (Dosing and Controls)	Lower	Higher
Flexibility	More	Specific
Proportion of ingredients	More accurate	Depends on integration of dosing system
Capacity	Can handle smaller and also varying volumes	Can handle much larger volumes
Mixing efficiency	Depends on operation	Depends on system design
Conclusion	Recommended for warehouse and small scale rice mills blending operations with low volumes	Suitable for large/medium rice mills with an existing continuous line

SELECTION OF BATCH BLENDER

The choice of batch blenders can be made based on comparison of blending attributes, material requirements and equipment specifications/ requirements. Table 5.2 illustrates such a comparison of four available batch blenders. Rotary blenders have been discarded since they are inefficient when the blending ratio of one commodity to another one is different.

Major factors to be considered while making the final selection of the blenders are marked with a '*' and also highlighted in bold font, and include:

- a. Suitability to grain blending (pellets versus powders, slurries, etc.);
- b. Gentleness of blending (least proportion of broken grains; See Figure 5.1);
- c. Low maintenance;
- d. Cost of the blender and blending;
- e. Time of blending; and
- f. Blending uniformity.

Rotary and V-cone blenders are very costly and are much more useful in pharmaceuticals, where the blending needs to be highly precise. As generally a coefficient of variation (CoV) of 15% or less is required for blending of fortified kernels, the precision blenders used in pharmaceuticals might not be needed.

Rice mills are usually high volume operations. Rice mills operate for around 20 hours a day, and if the blender capacity does not match the capacity of the mill, it will decrease the efficiency of the blending process and fortified rice production which is not a sustainable option. Mills usually also have space constraints. Hence the unit should be compact enough to fit into the milling environment.

CHAPTER 5: BLENDING EQUIPMENT SELECTION (continued)

Table 5.2. Comparison of selected blenders

MIXER ATTRIBUTES/ CHARACTERISTICS	BATCH MIXERS			
	Ribbon/ paddle/plow blenders 	Rotary batch blender 	V-cone blenders 	Fluidised bed blenders 
MATERIAL REQUIREMENTS				
Abrasive materials	Good	Excellent	Excellent	Fair
Brittle materials	Fair	Excellent	Excellent	Excellent
Chips	Fair	Excellent	Excellent	Excellent
Crystals	Fair	Excellent	Excellent	Excellent
Fibrous materials	Good	Excellent	Fair	Excellent
Fragile materials	Fair	Excellent	Fair	Excellent
Large variance in particle sizes	Fair	Excellent	Excellent	Fair
Pellets*	Fair	Excellent	Excellent	Excellent
Powders	Good	Excellent	Excellent	Excellent

Table 5.2. Comparison of selected blenders (continued)

MIXER ATTRIBUTES/ CHARACTERISTICS	BATCH MIXERS			
	Ribbon/ paddle/plow blenders 	Rotary batch blender 	V-cone blenders 	Fluidised bed blenders 
EQUIPMENT REQUIREMENTS				
Complete discharge	Good	Excellent	Excellent	Excellent
Gentle blending*	Fair	Excellent	Excellent	Excellent
Low maintenance*	Good	Excellent	Excellent	Fair
Lowest energy/amt. blended	Fair	Excellent	Fair	Fair
Lowest initial cost*	Excellent	Good	Good	Excellent
Rapid blending*	Fair	Excellent	Fair	Excellent
Rapid sanitising	Fair	Excellent	Excellent	Fair
Uniform blending*	Fair	Excellent	Good	Excellent

Excellent
 Good
 Fair
 Poor

CHAPTER 5: BLENDING EQUIPMENT SELECTION (continued)

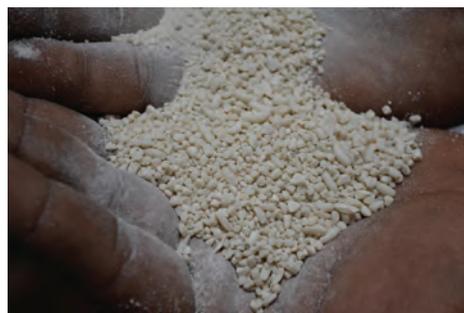


Figure 5.1. Proportion of broken grains after mixing is an important factor in the selection of blender



Figure 5.2. Rice blending inside the Forberg fluidised bed blender

The time of blending for ribbon blenders is around 20 to 30 minutes and to equal the capacity of fortified production in a rice mill, either very huge blenders or a large number of smaller blenders will be needed. Although, ribbon blenders are very economical and suitable for fortified rice production, the space requirement and time of blending cycle might make them unsuitable for use. But if these constraints can be addressed, these blenders can be considered for producing fortified rice. As an alternative, the Forberg fluidised bed blender is a batch blender with a much smaller blending cycle of 3 minutes per batch, and can also achieve the required blending homogeneity or CoV.

The strong points of the Forberg fluidised blender are summarised below:

- Highly **efficient, precise** and **gentle** blending in a **short** time;
- Allows comparatively high throughput; and
- As the blending time period is very short, it can be easily automated and run continuously batch-by-batch, meeting the rice mill capacity.

Hence, the smaller size Forberg blender could be a good option for efficient operation of a fortified rice production facility. **Keep in mind that the above discussion is only an illustration of the process for selection. Comparing blenders and final selection can be very different depending on the context and requirements of each specific operation.**

Example specifications of a Forberg blender (see picture of blender in Figure 5.3) are given below (can be different depending on the context and needs):

1. **Capacity** : 84 litres
2. **Mixing process** : Fluidized mixing principle using two counter rotating paddles.
3. **Mixing shell** : Horizontal with two semi-circular troughs in SS 304 construction
4. **Mixing elements** : Twin shaft with paddles in SS 304 construction
5. **Seal for mixer shaft** : Self-lubricating and water resistant design
6. **Feeding** : 1 inlet flange
7. **Ventilation** : 1 vent flange
8. **Discharge** : 1 discharge opening at the bottom end with a manually operated slide gate operated by rack and pinion.
9. **Power**
 - 9.1. Motor : Flanged motor
 - 9.2. Power : 5 HP, 3 Phase TEFEC, 50 Hz, IP 54
 - 9.3. Drive : Geared motor with chain and socket
10. **Control cabinet** : ON/OFF starter with indicator lamps

CHAPTER 5: BLENDING EQUIPMENT SELECTION (continued)

Forberg fluidised blender picture is given below. The engineering drawings of the blender are provided in the Annexes.



Figure 5.3. Side view of the Forberg fluidised bed blender

ADAPTATION OF EXISTING EQUIPMENT IN THE MILLS FOR CONTINUOUS BLENDING



Figure 5.4. Rice length grader adapted for use as a continuous horizontal blender

CHAPTER 5: BLENDING EQUIPMENT SELECTION (continued)

SELECTION OF CONTINUOUS BLENDERS OR RICE MILL LINE MODIFICATION

Blending by metering is a continuous mixing operation with metering devices. It can handle big volumes in a continuous system; initial capital costs are relatively high. Therefore there is also the possibility of adapting existing equipment in a rice mill setting for the purpose of continuous, high throughput blending. This can obviate the need to purchase new blending equipment and can lead to considerable cost savings and also improvement in efficiency in the production of fortified rice.

It has been reported that modification costs for fortified rice production can be reduced by approximately USD 8,000-10,000 per rice mill of 30 MT per day capacity by adaptation of the rice grader as a continuous blender. Rice graders or length-grading cylinders in a traditional rice-milling system are an example of existing equipment often available in a rice mill that can be adapted for use as a continuous blender (Figure 5.4).

Fortified kernels are fed using a pre-calibrated vibratory feeder as regular rice simultaneously goes to the grading cylinder. This is a continuous feeding method and helps to increase productivity. The length grader, by virtue of its grading mechanism, churns out the mix along with separating the broken grains from the mix. This churning helps in the uniform distribution of fortified kernels in the final fortified rice obtained at the rice outlet head of the length grader.

CHAPTER 6:

QUALITY ASSURANCE OF FORTIFIED KERNELS AND FORTIFIED RICE

CHAPTER 6: QUALITY ASSURANCE OF FORTIFIED KERNELS AND FORTIFIED RICE

Small- and medium-sized food-processing businesses all over the world have increasingly become aware that it is imperative to produce good quality products for their survival. In order to improve and control product quality, it is essential to fully understand the meaning of the term ‘quality.’ A common definition is “achieving agreed customer expectations or specifications.” In other words, the customer defines the quality criteria needed in a product. To meet this standard, the manufacturer puts in a QC system to ensure that the product meets the criteria on a routine basis.

OBJECTIVE

The quality check and quality plan section will help the staff responsible for fortified rice production to:

- Understand the QA and QC issues in manufacturing;
- Develop a quality plan to monitor the quality of product; and
- Implement corrective measures for quality issues encountered during manufacturing.

QC/QA

QC refers to a process by which entities review the quality of all factors involved in production. This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well-managed processes, performance and integrity criteria, and identification of records;
2. Competence, such as knowledge, skills, experience, and qualifications; and

3. Soft elements, such as personnel, integrity, confidence, organizational culture, motivation, team spirit, and quality relationships.

QA refers to the systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled. It is the systematic measurement, comparison with a standard, monitoring of processes, and an associated feedback loop that confers error prevention. This can be contrasted with QC, which is focused on process outputs.

Staff responsible for production of fortified rice can ensure QC by:

- Inspecting of raw material (RM) to ensure that no poor-quality ingredients are used;
- Carrying out checks during the process to ensure that the dosing rate of the raw material (fortified kernels and regular rice), feeder and blending parameters and packaging specifications are correct; and
- Inspecting the final product to ensure that no poor-quality product is sent to the consumer.

The QC approach is focused on the process whereas the problems that customers may face can also occur elsewhere in the production and distribution chain. Following are some important QC aspects, or a brief QC plan, for fortified kernels and fortified rice that a rice miller has to consider for meeting high-quality standards.

CHAPTER 6: QUALITY ASSURANCE OF FORTIFIED KERNELS AND FORTIFIED RICE (continued)

QUALITY PLAN FOR FORTIFIED KERNELS

The quality of the fortified kernels from the supplier needs to be monitored at least periodically. The quality manager may include the following tests for quality evaluation of incoming fortified kernels:

- Grain shape (rice like or nor), appearance (off colour or not) and odour (nil);
- Grain strength;
- Moisture content ($12.0 \pm 0.5\%$);
- KETT value (whiteness);
- Cooking quality (pass as per internal standards);
- Weight; and
- Broken content.

Internal standards should be developed where generally accepted standards are not available. In general, fortified kernels should comply with Codex standards. The processor must be able to demonstrate by principle and practice the adoption, implementation and recording of GMPs and HACCP.

QUALITY PLAN FOR FORTIFIED RICE

Refer to the Annexes for an example procedure for testing of blending efficiency of fortified rice. The quality manager may include the following tests for overall quality evaluation of fortified rice:

- **Coefficient of variation:** CoV of fortified kernels in the overall fortified rice blend should be $<15\%$. The target micronutrient content should be met by the fortified rice;

- **Cooking quality:** Fortified rice should withstand final preparation process (i.e., pre-washing, heat, high moisture, agitation, etc.) without compromising functionality, appearance, taste, and odor and target micronutrient content. Rinse resistant and cook resistant properties of fortified rice should assure levels of retention of each target micronutrient of at least 90% after rinsing and at least 80% after cooking;¹¹
- **Broken content:** Standards can be developed based on applicable regulations. For example, United States regulations¹² specify milled rice may include a maximum of 20% broken kernels or better for grade #5 milled rice; maximum 15% broken kernels or better for grade #3; and a maximum of 7% broken kernels or better for grade #2, with grades as defined in the latest 'Official United States Standards for Rice'; and
- **Microbial:** Microbiological tests should confirm fortified rice not exceeding maximum limits as per applicable regulations. For example, U.S. guidelines mandate the following limits for microbiological contamination: Salmonella, Escherichia coli and Staphylococcus aureus at 0 cfu/25 g, 0 cfu/g and 0 cfu/g, respectively; yeasts and molds at 100 cfu/g; and Aflatoxin B1, B2, G1 and G2 at 10 ppb.¹³

Internal standards should be developed where generally accepted standards are not available for the above and also any other appropriate tests. In general, fortified rice should comply with Codex standards. The miller must be able to demonstrate by principle and practice the adoption, implementation and recording of GMPs and HACCP.

¹¹ USDA Commodity Requirements: MR24 Milled Rice and Fortified Milled Rice for Use in International Food Assistance Programs. http://www.fsa.usda.gov/Internet/FSA_File/mr24.pdf Accessed December 17, 2014

¹² Ibid.

¹³ Ibid.

ANNEXES

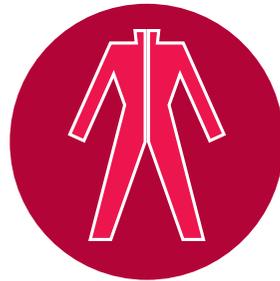
- 40 1. **Instructions for safety and hygiene in fortified rice production area**
- 41 2. **Guidelines for storage of fortified kernels and fortified rice**
- 42 3. **Guidelines for prevention of physical hazards during manufacturing of fortified kernels and fortified rice**
- 43 4. **Guidelines for preventive maintenance and housekeeping of blending machines**
- 44 5. **Template for maintaining records of calibration of equipment**
- 45 6. **Controlling the blending process through PLC – An example**
- 47 7. **Fabrication drawings**
- 51 8. **Testing blending efficiency – An example**
- 54 9. **Fortified grain producers**

ANNEX 1: INSTRUCTIONS FOR SAFETY AND HYGIENE IN FORTIFIED RICE PRODUCTION AREA

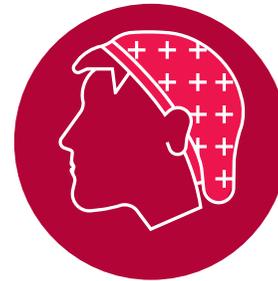
PROCESSING AREA



Wash your hands



Wear uniform



Wear hair net



Wear shoe cover



Don't wear
jewellery



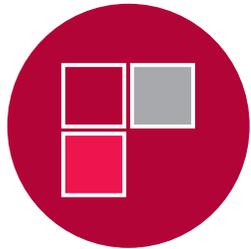
Don't chew
tobacco



No smoking

ANNEX 2: GUIDELINES FOR STORAGE OF FORTIFIED KERNELS AND FORTIFIED RICE

STORAGE AREA



Dedicated area for storage of RM/PM/FG



Make a note of all the receiving inventory



Visually inspect all items and look for signs of container damage



Store raw materials in cool dry place



Reject unacceptable goods and note on invoice

ANNEX 3: GUIDELINES FOR PREVENTION OF PHYSICAL HAZARDS DURING MANUFACTURING OF FORTIFIED KERNELS AND FORTIFIED RICE

PHYSICAL HAZARDS



Dirt



Hair



Nails, nuts and bolts



Insects



Broken glass



Staples



Plastic fragments



Bits of packaging material

ANNEX 6: CONTROLLING THE BLENDING PROCESS THROUGH PLC – AN EXAMPLE

The entire blending process is controlled by a PLC to ease the controlling process. The entire controlling process can be divided into various actions and linked through the PLC. The flow diagram of the blending process and the picture of PLC Panel are given below:

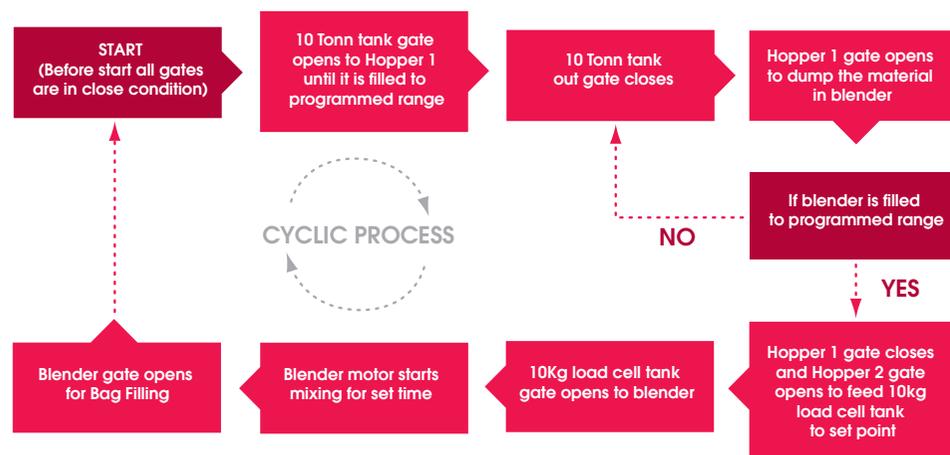


Figure A1. Logic of the PLC program

PLC Model : FX1S – 30MT – ESS
 HMI Model : SMARTLINE JR 2002 EX

Before starting the blending process using PLC, we need set the settings to run the program correctly. The settings we have followed are given below:

1. Press F8 button for opening the settings on the PLC screen. When we press F* button, the corresponding red LED light glows.
2. PLC asks for a password to change/modify the settings. Press enter.
3. Type the password (246) and then press Enter. The Settings screen is displayed.
4. MAIN MAX means, main load in maximum value in kilograms. Enter the maximum value as 400 which means 400Kg.
5. DOSE MAX means, maximum value of dosing in grams. Type 10000 which means 10Kg.
6. MAIN SET means, the setting value of Main Load. Enter the value of traditional rice to be loaded for every run. During trials, we used 25Kg for every trial run. Hence we entered 25Kg.
7. DOSE SET means, dosing value of Ultra Rice. This will automatically set with 100:1 ratio. In this case it will be automatically set to 250 grams as we have used 25Kg of traditional rice.
8. MAT DMP OF DLY means delay we are planning while dumping traditional rice and Ultra Rice to the blender in seconds. We entered 10 seconds to feed the material to the blender.
9. MIXER ONDLY means blender mixing time in seconds. We used various blending times like 60, 120 and 180 seconds.
10. MAT OUT ONDLY means, the time we need to dump the blended produce out which is 60 seconds in our case.
11. After setting these values, Press F8 again to exit from the settings menu. The LED light goes off.

ANNEX 6: CONTROLLING THE BLENDING PROCESS THROUGH PLC – AN EXAMPLE (CONTINUED)

USING THE PLC FOR OPERATING STEP BY STEP:

Set the PLC to Manual Mode using the selector switch on the Panel.

1. Press F1 to operate main coarse solenoid valve. It feeds till the rice weighs 24Kg with a coarse flow.
2. Press F2 to operate main fine solenoid valve. It feeds rice till it reaches 25Kg with a fine flow.
3. Press F3 to open the gates of the Main hopper to feed the rice to the blender.
4. Press F4 to start the vibratory feeder. It will stop when the feeding hopper gets 250 grams of Ultra Rice.
5. Press F5 to open the feeding hoppers valve and feed the Ultra Rice to the blender.
6. Press F6 to start the Mixer Motor.
7. Press F7 to open the dumping out solenoid valve to dump out the blended produce.

When the HMI buttons (F1 to F7) are pressed, the LED light for a particular operation glows, denoting that particular operation is going on.

USING THE AUTO MODE OPERATION:

Select the auto mode using the selector switch on the Panel.

Before starting the operation make sure that the tear weight mentioned in the panel is set to zero.

1. Press the Start button to start the operations and Stop button to stop the cycle.
2. Press the start button.
3. Main coarse, Main fine and the Dosing units are turned on and start filling.
4. While filling the rice, as the rice weight reaches the set value (around 24Kg) the Main Coarse filling stops and fine filling continues until the weight reaches 25Kg. Once it reaches 25Kg the valve feeding rice with a fine flow also shuts.
5. Then the feeder starts and fills corresponding Ultra Rice weight to the feeder hopper (in this case, 250 grams) and stops.
6. Both the main and feeding hopper gates will be opened feeding the rice to the blender.
7. Then after 10 seconds, the valve will be closed and starts taking the next load. Simultaneously the blender starts blending action for the set value (for either 60/120 or 180 seconds).
8. Once blending stops after the set time, the dumping out valve opens for specified time discharging the blended produce out from the blender and closes after the set time.
9. Once this valve is closed, the cycle starts again from point number 3.

The simultaneous filling of regular rice and fortified kernels for the next cycle while blending and discharging is going on may not be programmed, to avoid aberrations in weighing caused by the mechanical vibrations of the blender.

ANNEX 7: FABRICATION DRAWINGS

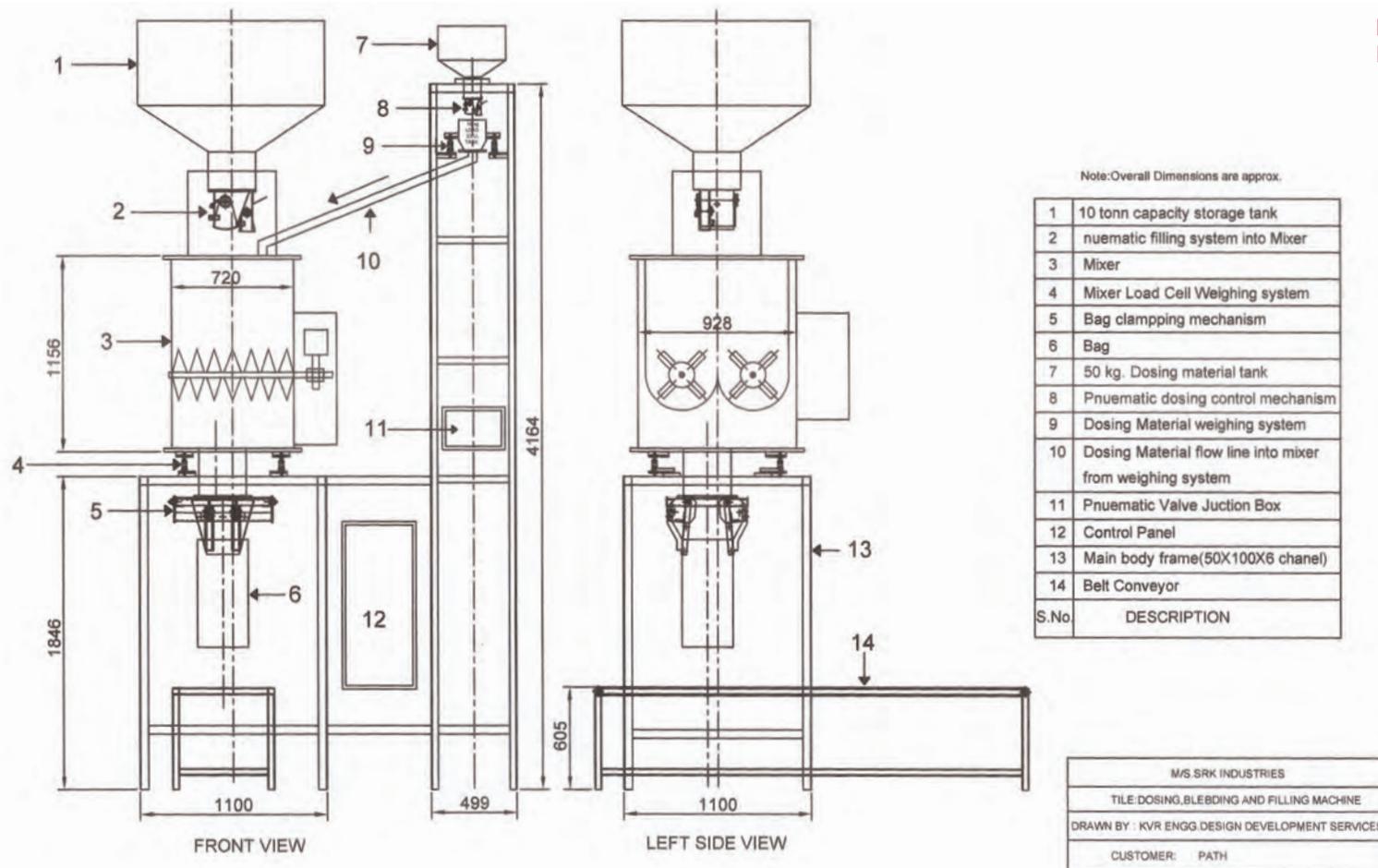


Figure A2. Front and side view of the blender system

ANNEX 7: FABRICATION DRAWINGS (continued)

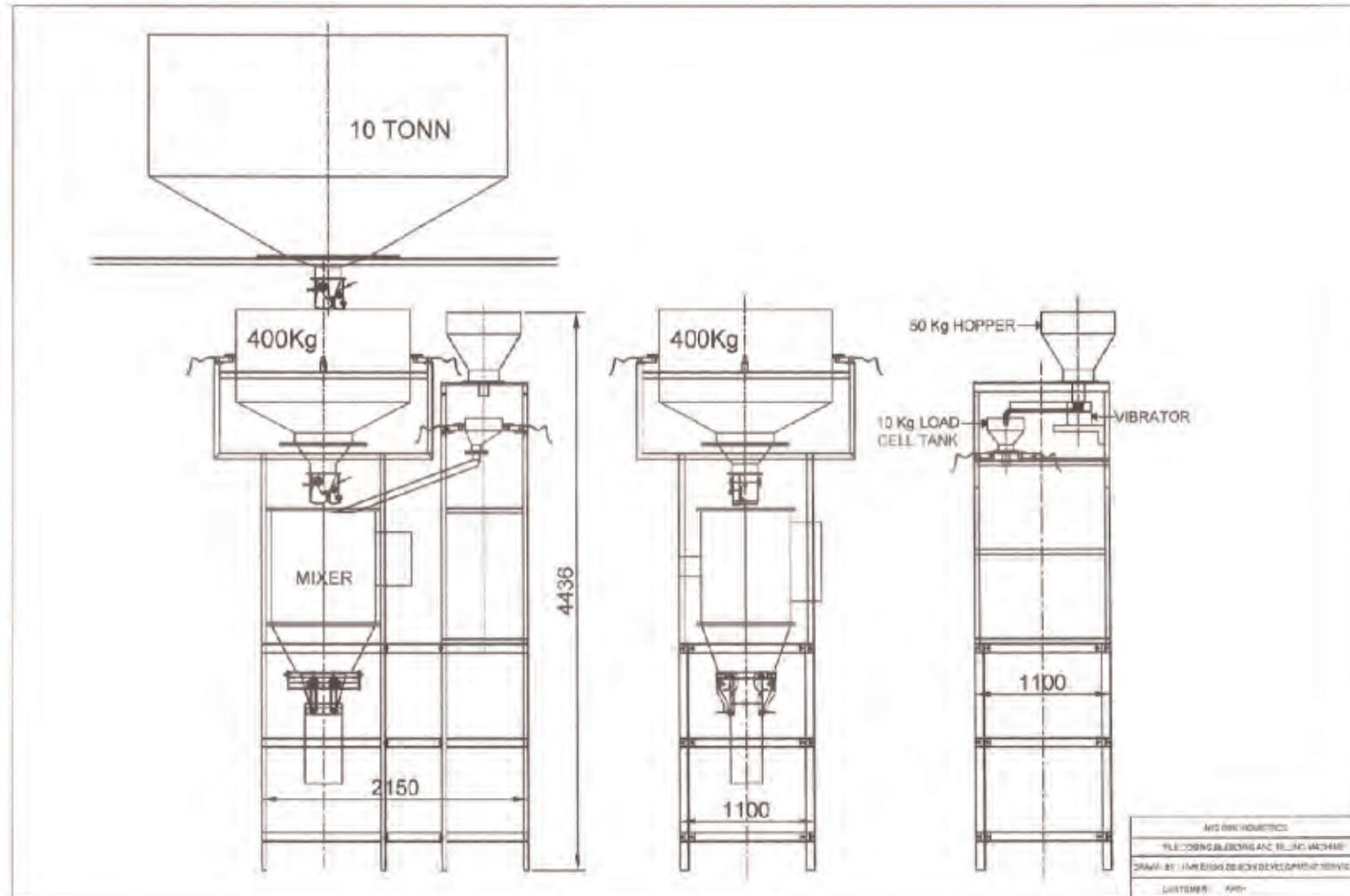


Figure A3. Frame and hopper assembly

ANNEX 7: FABRICATION DRAWINGS (continued)

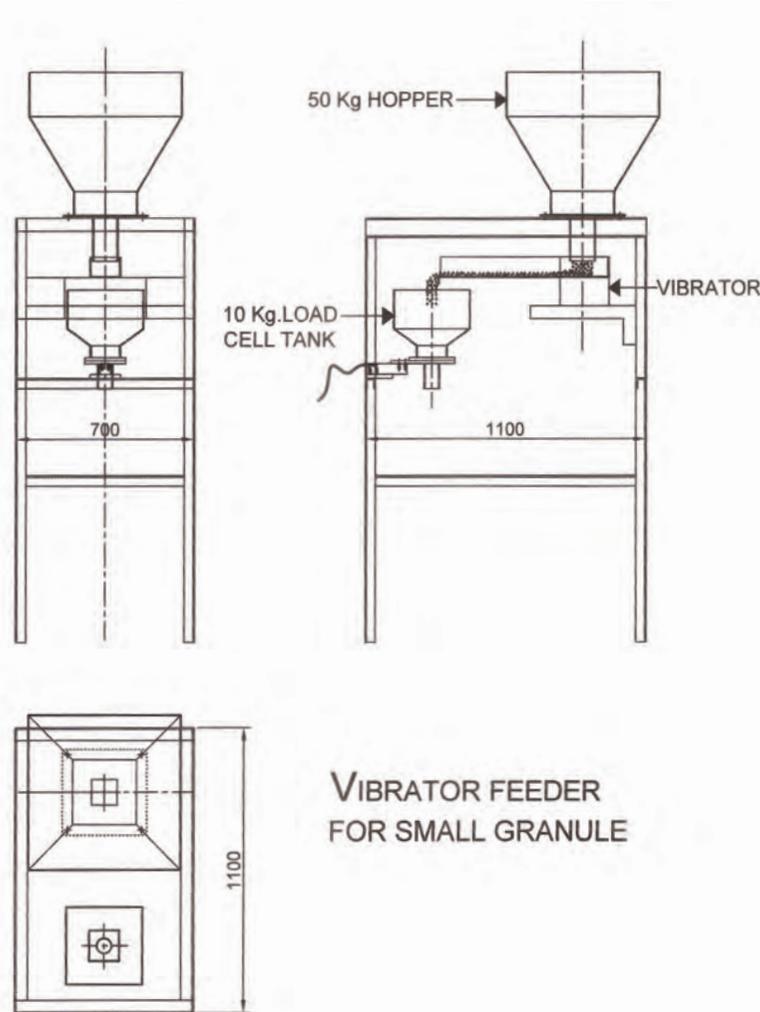


Figure A4. Vibrator feeder

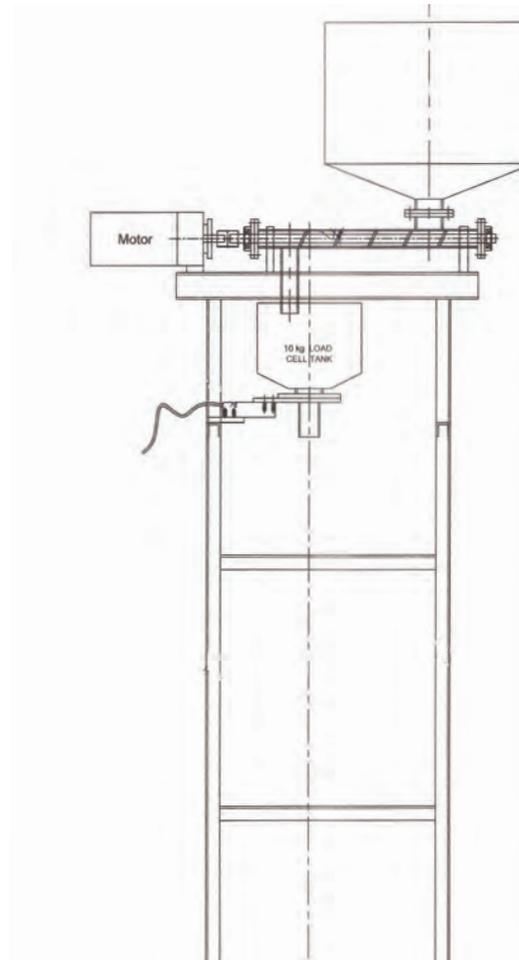


Figure A5. Screw feeder system

ANNEX 7: FABRICATION DRAWINGS (continued)

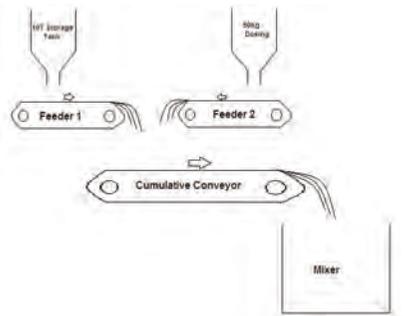


Figure A6. Conveyor feeder system

ANNEX 8: TESTING BLENDING EFFICIENCY – AN EXAMPLE

After installation and incorporation of feeder and blender system into the rice mill, it is important to test the performance of the blenders for various parameters such as: a) Blending homogeneity, b) Broken grain percentage, c) Power consumption and d) Labor requirement against various blending times and blending speeds. An example of such a test conducted in a particular fortified rice facility is given below.

SPECIFICATION OF RICE

Basic information of the rice to be fortified should be noted after analyzing a representative. An example is given below.

- i. Rice variety : Sona masuri
- ii. Milling condition : double polished
- iii. Milling method : parboiled
- iv. Mill type : rubber rollers
- v. Average length : 6.23 mm
- vi. Average breadth : 1.8 mm
- vii. L/B ratio : 3 – 3.4
- viii. Broken percentage : < 0.25% (Broken grain less than 2/3rd of average grain length)
- ix. Moisture content : 12%

TESTING PARAMETERS

A power meter should be installed to measure the power consumption during the trials. The blending efficiency should be tested at different blending speeds (example: normal, 20% slower and 20% faster) and different times of blending cycle (example: 1, 2 and 3 minutes). Different dosing systems can also be tested for efficiency following the same procedure, for example, vibrator feeder, screw feeder and conveyer feeder. The feeding process for both regular rice and fortified kernels can be semi-automated using the PLC (programmable logic controller; Figure A7) in combination with load cells to achieve gravimetric delivery. Possible test parameters are listed below.

Doser variant:

Feeders in combination with the blender should be tested for the homogeneity of mixing, change in the broken percentage because of blending, operational feasibility at miller level, etc.

1. Vibrator feeder – VIB
2. Screw Feeder – SCW
3. Conveyer Feeder – CON

Cycle time variant:

1. 3 minutes of cycle time – 3
2. 2 minutes of cycle time – 2
3. 1 minute of cycle time – 1

Blender rpm variant:

1. 50 rpm – 50
2. 60 rpm – 60

ANNEX 8: TESTING BLENDING EFFICIENCY – AN EXAMPLE (continued)



Figure A7. Final blended fortified rice falling out of blender outlet



Figure A8. Semi-automated PLC display

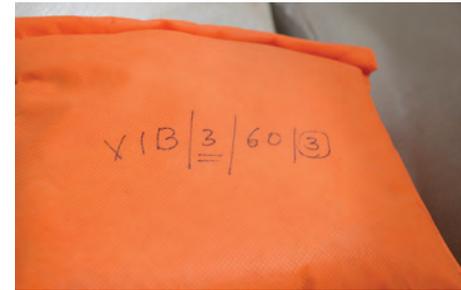


Figure A9. Fortified rice sample nomenclature. Sub-sample collected from running the combination of vibrator feeder and Forberg blender with a blending cycle period of 3 minutes



Figure A10. Calibration of dosing/feeder equipment and speed of 60 rpm

SAMPLING PROCEDURE

At least three samples from three different locations should be obtained after blending, following BIS method of sampling and tested for homogeneity. Each sample should be divided into three subsamples of 400–500 grams and numbered 1, 2 and 3.

1. Sub sample 1 will be used for spot testing. The criteria which can be tested include homogeneity based on number of fortified kernels and broken grains.
2. Sub sample 2 will be sent to the lab for testing the iron content, broken percentage, moisture content etc.
3. Sub sample 3 will be stored for future reference.

Samples should be given appropriate identifier/name. An example would be as follows: Doser variant/cycle time variance/rpm variant/sub-sample number (Figure A9).

ANNEX 8: TESTING BLENDING EFFICIENCY – AN EXAMPLE (continued)



Figure A11. Example blending setup – rice length grader adapted for use as a horizontal blender

The final CoV of fortified kernels in the fortified rice should be within 15%. In similar tests, it has been established that rice length graders (see Figure A11), normally used to separate broken grain from the milled rice in an existing milling setup, can be used as blenders to produce a homogenous mixture (within specified CoV) of traditional rice and fortified kernels. With proper calibrations and modification to



Figure A12. Testing blending efficiency – visual inspection of broken/ crushed/ powdered rice

the entire system, continuous constant feeding and homogenous blending can be achieved using existing graders in the rice mills. This avoids purchase of a blender altogether and lowers capital costs. CoV can be further improved by scientifically assessing the rice flow of the mill and also calibrating the feeder for a constant fortified kernel feeding in a continuous milling system.

ANNEX 9: FORTIFIED GRAIN PRODUCERS

ADORELLA ALIMENTOS LTDA – BRAZIL

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www.adorella.com.br

URBANO AGROINDUSTRIAL LTDA – BRAZIL

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Tel: 0800 475051
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WUXI NUTRIRICE CO. LTD. – CHINA

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UNION DE ARROCEROS S.A – COLOMBIA

Carrera 7ª Sur No. 49 - 23 Zona Industrial El Papayo
Ibagué – Colombia
Teléfono : (8) 2650542
www.arrozsupremo.com/index.html

DSM/VIGUI – COSTA RICA

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Tel: (506) 2244-4087
www.vigui.com

GRUPO NTQ – COSTA RICA

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FOR MORE INFORMATION

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ABOUT PATH AND GAIN



PATH is the leader in global health innovation. An international nonprofit organization, PATH saves lives and improves health, especially among women and children. PATH accelerates innovation across five platforms—vaccines, drugs, diagnostics, devices, and system and service innovations—that harness its entrepreneurial insight, scientific and public health expertise, and passion for health equity. By mobilizing partners around the world, PATH takes innovation to scale, working alongside countries primarily in Africa and Asia to tackle their greatest health needs. Working together, PATH and its partners deliver measurable results that disrupt the cycle of poor health. Learn more at www.path.org



The Global Alliance for Improved Nutrition (GAIN) is an international organization launched at the UN in 2002 to tackle the human suffering caused by malnutrition. Today nearly 3.5 billion people worldwide are malnourished in some way. Close to 2 billion people survive on diets that lack necessary vitamins and nutrients, while about 1.4 billion people struggle with overweight and obesity. We know that sustainable, nutritious diets are crucial to ending the cycle of malnutrition and poverty. By building alliances that deliver impact at scale, we believe malnutrition can be eliminated within our lifetimes. Today our programs are on track to reach over a billion people with improved nutrition by 2015. For more information about GAIN, please visit www.gainhealth.org

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