expensive to handle and dispose. Accumulated waste can stop production and cause sanitation problems. Ingredients should be purchased, products formulated and processes designed to minimize, reuse or provide an alternate use for waste. Many large-scale processors are discovering that waste handling, treatment and disposal pose severe growth limitations on production. Product residue in equipment such as pumps, piping, tanks and conveyors also should be considered.

Storage

Storage requirements for raw ingredients, packaging materials, labels and finished product increase on scale-up. Storage requirements are simple to determine, but are often forgotten. Refrigerated storage of ingredients and products should be minimized to keep costs low.

Packaging

Packaging frequently costs more than the food product it contains. With this in mind, it is important to minimize packaging costs from the beginning. Consultation with a reputable packaging supplier should solve most of the scale-up issues. Some of these issues are:

- Physical strength of the package with regard to filling and packing machinery and intended stacking height
- Ability of the package to withstand temperature changes
- Neck diameter and headspace
- Closure type and integrity
- Safety or tamper evident seal
- Ability to accept the desired label
- Aesthetics
- Product code and pack date markings
- Weight (for shipping)
- Secondary (case) and tertiary (pallet) packaging requirements

Facility Scale-up

Frequently, a contract packager, or co-packer, will initially be selected to manufacture the product. It may not be wise to invest in process equipment until the product is established in the market place with a proven sales track record. Co-packers can be selected by reviewing their costs of services, production records and experience with similar products. Obtain product samples if possible and evaluate them according to an objective quality criterion. Insure that the co-packer is willing to provide an agreement of confidentiality to protect the recipe. Ask to see proof of product liability insurance, examine the co-packing contract and evaluate the co-packer's own financial soundness.

Rework

A provision for product rework or recovery may be desirable for large-scale production. Rework can occur if the wrong label is applied to a product, or if a product is improperly batched. A rework plan can result in salvaged product rather than discarded materials.

Inspection

Products made in the kitchen receive individual inspection by the same person throughout the entire process. Product inspection often becomes more difficult on scale up because of the larger numbers and volumes. Additional personnel and/or machinery must be employed to inspect containers, ingredients, process steps, labels, packaging and other items. Product uniformity and control become issues of concern.

Recalls

The event of a product recall is rare and unfortunate. Proper planning can help minimize the expense of a recall. Procedures and records must be maintained to enable the tracking of all ingredients, packaging and finished product throughout the production and distribution systems.

Sanitation Program

A formal, documented sanitation program must be developed to insure cleanliness of the production facility. Information on a basic sanitation program can be obtained in the fact sheet, "FAPC-121 Process and Facility Sanitation," available for download at http://fapc.okstate.edu/PAGES/facts.htm.

Supplier Certification

Wholesome, clean and consistent ingredients and packaging materials are needed to produce high-quality food products. Suppliers and their manufacturing facilities and distribution networks should be carefully evaluated before being selected for the scaled-up process. A low-priced supplier may cost more in the long run in terms of loss of product quality, rework and recalls. Meet with potential suppliers and request written certification of their products that are referenced to known quality standards.

Conclusion

Food product scale-up is an exciting and challenging process that requires an organized, flexible and consistent approach for success. Success is often celebrated when a suitable recipe and process for commercial production has been determined. True success, however, is best measured in terms of profitability and customer satisfaction over time, which are the ultimate result of successful scale-up of a food process.

Robert M. Kerr Food & Agricultural Products Center

FOOD TECHNOLOGY FACT SHEET

Adding Value to OKLAHOMA

405-744-6071 • www.fapc.biz • fapc@okstate.edu

Scaling Up Your Food Process

Darren D. Scott
FAPC Food Scientist

Timothy J. Bowser, P.E.
FAPC Food Engineer

William G. McGlynn
FAPC Horticulture Processing Specialist

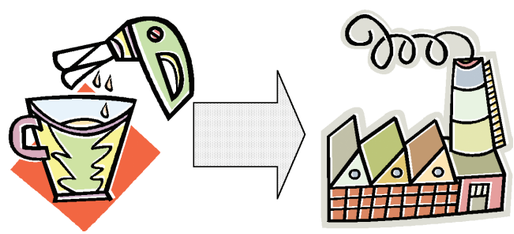
Introduction

Food products typically start with a recipe that is formulated and tested in a kitchen. Once a satisfactory product is obtained, the next step is to scale-up the recipe for mass production, packaging, distribution and sales. The scale-up process has many pitfalls that can ruin the best-laid plans for commercial production. Ingredients may behave differently, flavors change and equipment issues arise. The purpose of this fact sheet is to identify and discuss some of the key issues in the scale-up of food processes.

Formula Scale-up

Scaled-up batches of product may be very different from the original formula because of differences in taste, texture, aroma or appearance. It may be possible to modify the scaled-up formulation so that it more closely resembles the original, but it may not be possible to make them identical. This is not unusual because foods are a complex mix of interacting chemical and physical systems. As these systems become larger, the ways in which they function may change. Therefore, the scale-up process is not necessarily straightforward and may require multiple attempts and trial and error.

It should be noted that many times the scaled-up batches are often no better or worse than the original, just "different." These products often receive a higher degree of scrutiny and their increased size makes it much easier to observe "flaws" that may in fact be present in the original formulations as well. A certain degree of flexibility may be required when evaluating alternatives so that a commercially feasible product can be manufactured.



Simplification

As mentioned previously, foods are often complex interacting systems that do not necessarily behave the same way after scale-up. Therefore, "simplified" formulations tend to scale-up more easily and may also be less expensive to produce. Several factors can be used to simplify product formulations:

1. Functionality

Are there other ingredients that do the same job? There are often ingredients with specific functionality that may be used to replace home style ingredients in scaled-up batches. Bread crumbs can be used as a thickening agent in home recipes. However, in a commercial batch starch may be more appropriate. Starch comes in a variety of forms that can provide the same functionality as the bread crumbs in a more reliable manner over a broader range of conditions.

2. Form

How similar are the ingredients? A product formula that consists of either a few dry ingredients or a few wet ingredients will probably scale-up easier than a formula that contains many different wet and dry ingredients. For example, a formulation for a spice blend might scale-up easier than a formula for a gelatin salad. Likewise, formulas that contain ingredients of a similar color might scale more easily than a product with many different colors. For example, a red beverage might scale-up easier than a candy with red, blue and purple stripes.

3. Cost

Is a less expensive ingredient available? Sometimes alternative ingredients can be found that are less expensive than those in the original home recipe. For example, weight-for-weight starch is often a less expensive thickening agent than bread crumbs.

4. Availability

Will the ingredient be on hand when needed? Many fresh ingredients are seasonal. Items such as herbs are plentiful during warmer months, but may become unavailable when the weather turns colder. Oleoresins and essential oils of herbs are available year round and offer very similar flavors.

Units of Measurement

Home recipes based on pinches and dashes can be notoriously variable since these are not standardized units and can vary from person to person. An excellent way to reduce this variation is to convert the recipe to standardized units of weight or volume. However, it should be noted that while units such as teaspoons and cups are standardized units, they are relatively small and will still need to be converted. It is much easier and less time consuming to measure out 50 gallons of water rather than 38,400 teaspoons.

Kilograms, pounds, grams and ounces are common weight measures and gallons and liters for volumetric measures are also not unusual. The production process can be streamlined by using these units. However, some items may need to be converted from units of volume to units of weight, depending upon how the food will be processed and what equipment is available.

A common error is to mistake fluid ounces for ounces by weight. While one cup of an ingredient does equal eight fluid ounces, it does not necessarily equal eight ounces by weight. For example, two cups of foam packaging peanuts do not weigh one pound (16 ounces). Therefore, it is very important to keep this in mind when scaling up a formula so that values are correctly converted to the proper weight.

Other Formula Scale-up Issues

Some ingredients tend to be more problematic when scaling up than others. Often colors of spices may run or bleed when they are mixed together with lighter-colored ingredients. For example, black pepper mixed in with lighter-colored ingredients can result in a gray or muddy appearance.

Fresh items such as fruits and vegetables may be difficult to work with. When scaling up these items, it is important to consider whether or not the entire commodity is to be used or whether the commodity will need to be peeled, cored or seeded.

Process and Equipment Scale-up

The first step in process and equipment scale-up is to define the product and package matrix. This includes a product definition, the size and type of package desired and the production rate. An example of a product and package matrix is given in Table 1. At this time it is best to include future requirements in the matrix. A future projection of

Table 1. Product and package information matrix.

PRODUCT	production rate MIN	production rate MAX	PACKAGE
Example I: 1 cc capsule of pure emu oil (red or green)	50 cases/week	75 cases/week	250, 500 and 1,000 caps per plastic bottle with cotton insert and plastic shrink band. 12 bottles per case.
Example II: 1 cc capsule of pure emu oil (red or green)	500 caps/min phase I	1,000 caps/min phase II	Same as example I
Example III (future): 5 cc capsule of emu oil and aloe (blue or brown)	250 caps/min phase I	500 caps/min phase II	Mini 50 and Jumbo 5,000 count in plastic bottle with heat-activated foil seal and cotton insert. 48 minis and 6 Jumbos per case.
Example IV: Healthy, fortified fruit drink	500 gallons per day	750 gallons per day	6 and 12 oz reusable, plastic “sports” container. 24 bottles per case.

product and process requirements is a proactive means to build maximum flexibility into a production line. It is desirable to obtain or manufacture actual product samples or purchase similar product and packaging samples for discussion purposes with suppliers and consultants.

Major changes in process equipment requirements can occur when scaling up from kitchen to production volumes. This is due, in part, to the physical laws governing the unit processes involved. Heat transfer (cooking and cooling) and mixing in tanks or vessels are two of the most common treatments in food processing. Both of these treatments are heavily dependent on the unit surface area (Sa) to volume (Vol) relationship. Surface area refers to the actual surface area (in square feet or square meters) of a cooking or mixing vessel that contacts the product. Volume (Vol) refers to the quantity of the product being batched (gallons or liters).

The ratio of surface area to volume (Sa/Vol) normally changes during the scale-up process. For example, the Sa/Vol ratio is reduced by nearly a factor of two when scaling up from a 20-quart kitchen stockpot to a 100-gallon hemispherical tank (hemispherical tanks are common cooking vessels found in commercial kitchens). The decrease in Sa/Vol indicates that there may be a major difference between the mixing and heating characteristics of the two vessels. The ratio becomes much more important for temperature-sensitive and difficult-to-mix materials. Burn-on is often a problem on scale-up, since higher temperatures are needed at cooking surfaces to speed up heat transfer to the product. Table 2 lists common scale-up issues for mixing and heating processes.

Batch Versus Continuous Processing

Batch processing is the traditional means of preparing food products. A specified volume or mass of ingredients are combined and undergo processing simultaneously as unit (such as mixing or cooking) before being transferred to a further processing step (e.g. canning). Continuous processing means that the product is constantly moving through the system and is not held “captive” for any length of time. Combinations of batch and continuous processes are common. For example, ingredients for ice cream are often batched in large tanks, which are continuously pumped into a freezer system which chills the product as it is being transferred to the next processing step. Both methods have advantages and disadvantages that must be considered on an individual case basis. Normally, continuous processing requires less hold time and handling of product. Batch processing allows more control of discrete units of production.

Product Transfers

Movement of product from step to step in processing may become more complex on scale-up. Pumps, valves and piping are required to handle liquid materials. Conveyors and pneumatic tubing handle solids. Automatic lifts and dumping devices are necessary for heavy mixing bowls and containers. Thoughtful positioning of tanks and process equipment can minimize product transfer requirements. When possible, elevated equipment may be used to gravity-feed product to the next step. Openings on conveyors and tanks should be covered to prevent contamination of product from outside sources.

Waste

Product waste is often unaccounted for in scale-up plans. Waste from food processing operations can be

Table 2. Common scale up issues for mixing and heating.

MIXING	HEATING
Dispersion of ingredients	Burn-on
Mixing time limitations	Heating time limitations
Power requirement	Heating media (steam, electric, hot water, gas, or other)
Materials handling (filling and emptying tank)	Hold time (product quality)
Hold time (product quality)	Cleanup and sanitation
Incorporation of air	Materials handling (pumping, filling and emptying tank)
Cleanup and sanitation	
Changes in physical characteristics of materials (e.g. particle size reduction, color, volume, thickness)	