Update on Micro Fruit and Vegetable Processor

The NUS team (05 Nov 2010)

Outline

- Detailed Processing Steps of Vegetable Paste Using Pressure Sterilizer
- Optimal Processing Conditions
- Nutritional Results
- Pressure Gauge Precision Issue
- Future Plan
- Supplementary: Principles Of Retorting And Pressure Cooking

Detailed Processing Steps of Vegetable Paste Using Pressure Sterilizer

- **Washing**
  - Caixin, long bean and carrot
  - Soak soy beans overnight in tap water.
- **Blanching**
  - Caixin and long bean blanched @ 93-94°C for 1 min
  - Carrots are peeled off the skin and cut into around 1inch slice, then blanched @ 93-94°C for 3 min.
  - Note: different research studies showed different temperature-time combination. The condition used here was a common one in some studies.

- Purpose of blanching
  - inactivates endogenous enzymes that would otherwise cause quality deterioration
  - expels air from the plant tissues
    - reduces the potential for oxidative reactions in the later thermal processing
    - increases the thermal conductivity of plant tissues → improve heat transfer
  - serves as a cleaning process
  - reduces the volume of bulky vegetables by wilting

- **Cooling**
  - Soak all the blanched vegetables immediately after blanching in room temperature tap water for around 1.5-2 min.
  - Purpose of cooling
    - Reduce the loss of oxidizable vitamins (e.g. vitamin C and carotene)
    - Retard spoilage bacteria
    - Prevent colour loss

- **Blending**
  - What we did in our simulation experiment. It will be different if using a machine.
  - Caixin: blended into small pieces using homogenizer.
  - Long beans: cut into small segments around 1.5cm long using a knife
  - Carrots: blended into small pieces using homogenizer
  - Soybeans: no blending.

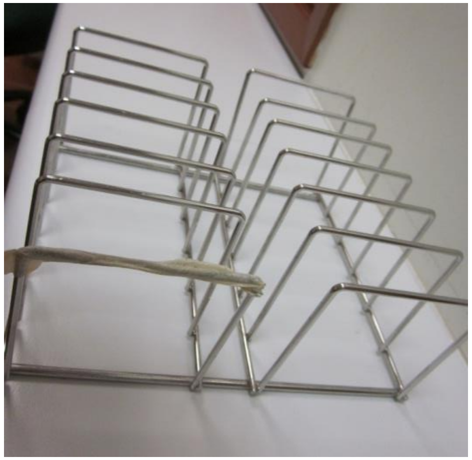
- Mixing
  - Measure the blended vegetables and mix with other ingredients
  - Caixin: a lot of water was leached out after blending, so most leached water was drained out before weighing.
  - Formulation:

For 100g vegetable paste	
Carrot: 30g	Salt: 1g
Caixin: 35g	Sugar: 0.7g
Long bean: 15g	Pepper: 0.2g
Soy bean: 20g	Vinegar: 1g

- Filling
  - 4 layered pouches from China are used
  - 100g per pouch
  - Avoid contamination of sealing area
- Sealing
  - Vacuum seal: 95% air removal, then sealing for 8 sec (max duration).
  - However, the percentage may not be exactly accurate due to both machine inaccuracy and product nature (not as dense as dry beans).
  - The machine can be adjusted to 99% but the results were not optimal during initial trials.

Vacuum sealer used in our experiments

- loading to the pressure cooker
  - Before that, ensure enough water in the outer pot. And we added around 400ml in the inner pot as more water caused leakage from the top valve. By calculation, 400ml water is more than enough to generate steam filling up the pot volume.
  - Pouches are put in the metal rack which came along with commercial retort machine in Singapore Poly.



- Pouches are not in contact with water for pure steam sterilization.
  - Seen from the picture in the previous slide, we put a stainless porous bowl + a round stainless layer underneath the rack.
  - As metal rack cannot stand steadily on the bowl alone, we need the round stainless layer in the between.
- Pouches are not in contact with the pot surface as it may be a higher temperature than the steam, which could increase the burst open rate.

- Retorting
  - At the start, open release valve, close safety valve.
  - At 15 min after switching on, close release valve.
    - Water has already started boiling and steam generated. Air is expelled from the pot.
    - If not, steam-air mixture will cause underprocessing as air is a poor heating medium, and product center wont reach the desired temperature.
  - Usually at 26 min after switching on, temperature reaches 123°C.
  - Maintain the temperature by on and off the plug for 20min.
    - Temperature control has to be quite precise. Better to no higher than 123.3°C from experiences.

- Depressurize after 20min sterilization
  - Open the safety valve a bit. The release valve remains closed
  - Dpressurization has to be very slow. (1°c drop per min, and entirely takes ~16min)
  - Can see and hear steam coming out from the safety valve during the depressurization process
- Cool the pot for 10min after fully depressurization.
  - After fully depressurization, open the release valve.
- Open the pot and take out the samples
  - Cool pouches in the tap water at room temperature for 15 min (the temperature inside pouch can reduce to 35-40°C, which is microbially safe.)
  - Some pouches cooled naturally for comparison study (it takes nearly1 hour at Singapore outside ambient temperature to reach the temperature range above.)
  - Note: 1ppm chlorine water is commonly used in industrial canning process to prevent microbial contamination from sealing area.

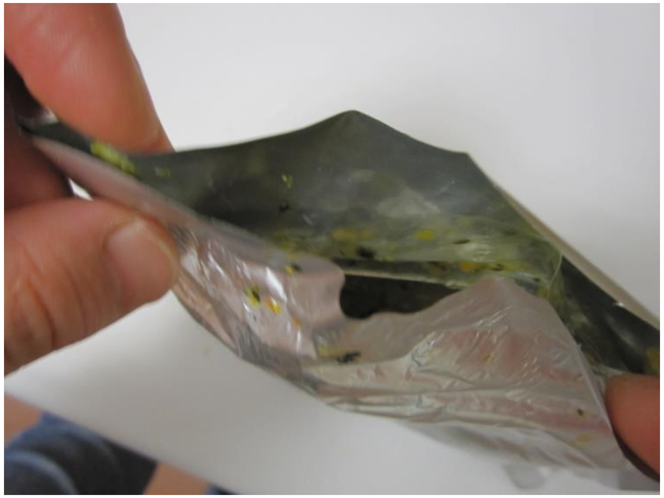
Optimal Processing Condition Results

Preliminary tests

Processing condition	Sealing and cooling	Average log reduction
121°C, 10 min	Vacuum, ice	-0.01
	Vacuum, water	0.08
121°C, 20 min	Vacuum, ice	0.17
	Vacuum, water	0.12
121°C, 30 min	Vacuum, ice	0.39
	Vacuum, water	0.21
122°C, 30 min	Vacuum, ice	0.79
	Vacuum, water	0.89
123°C, 10 min	Vacuum, ice	0.23
	Vacuum, water	0.24
123°C, 15min	Vacuum, ice	1.71
	Vacuum, water	1.01
123°C, 20 min	Vacuum, ice	2.21
	Vacuum, water	2.14

- Repeats of trials at 23C, 20min proved to reduce at least 2D of microorganism, *Bacillus Stearothermophilus*.
- The packaging failure rate is maximally 2 pouches per run (12 pouches) through longer depressurization time of 17 to 20min and more precise temperature control. (refer to process steps details)
- More explanation on pouch burst open rate later.

Two pictures show two sides of the same pouch. The sealing was damaged on one side compared to the one on the right.



This is the same pouch as shown above. The plastic layers were separated. There is a hole in the picture. Two layers around the hole were originally adhered together as one side of retort pouch.

Nutrition Results

Essential Nutrients Content in the **Final Product**

Nutrients	Amount per serving size 200g	Daily Value (from USDA)	Percentage of Daily Value
Protein (g)	8.86	50	17.7%
Total Fat (g)	3.32	65	5.1%
Total Dietary Fiber (g)	3.00	25	12.0%
Vitamin C (mg)	5.24	60	8.7%
Vitamin A (IU)	1535.92	5000	30.7%
Vitamin E (α-tocopherol) (mg)	2.40	20.1	11.9%

Vitamin C is measured as ascorbic acid only. Theoretically, Vc should contain both AA and dehydroascorbic acid. (DHAA) However, DHAA has been an analytical challenge to research and there is lack of a reliable method.

Analysis on essential nutrients contents

- Except vitamin C and fat content, the final product can be claimed as the **good source** for all the rest nutrients.
  - To claim as good source of a nutrient, the product has to contain more than 10% of daily value of that nutrients.
  - Fat content and vitamin C are not the main focused nutrients in the project, as vitamin C can be easily lost during cooking and fat can be supplemented by taking many other kinds of foods.
- Protein and Vitamin A are important nutrients as Cambodian diets are deficient in these two nutrients.
  - Vitamin A content in the final product can give around 1/3 daily required intake. Our objective for V A is met.
  - Protein content is lower than 1/3 daily required intake. We will further modify the formulation to achieve a better nutritional profile.

Effect of processing on micronutrients

	AA	RAE	a-tocopherol	TC	TVE	TPC
	mg/g	ug/g	ug/g	mg/g	ug/g	mg GAE/g
Raw vegetable mixture	0.569	16.74	87.18	0.42	192.40	3.37
Before Retorting	0.257	17.29	83.06	0.33	176.82	3.36
After Retorting (123C,20min)	0.128	11.53	59.11	0.20	170.26	2.90

Table above is on dry weight basis.

RAE=retinol activity equivalent=3.33 IU. Both are used in nutrition database.

Vitamin E usually uses a-tocopherol value in the nutrition database .

TVE=Total Vitamin E Vitamers, TC=Total Carotenoids, TPC=Total Phenolic Content

TVE, TC and TPC are all antioxidants associated with a wide range of health benefits.

- All nutrients showed decreases after retorting. And decrease of vitamin C is the most significant.
  - Vitamin C decrease may be due to the oxidation by remaining air in the pouch.
- All nutrients showed little effect of blanching by comparing raw vegetable and before retorting samples, except vitamin C.
  - Vitamin C lost around 50% in the blanching step.
  - Increase in RAE is due to the better extraction efficiency after blanching.

Pressure Gauge Precision Issue

And temperature recording device results

A Serious Issue of Our Pressure Gauge

- **Pressure gauge on the lid does not show the true temperature of the heating medium.**
  - Gauge shows 123°C.
  - Temperature Recording Device (Ellab) showed the maximum medium temperature is only 107°C, and the maximum product temperature is 105°C.
    - Under this condition, the microbes even cannot be killed by 1D reduction. Theoretically, it should be 0.2D. Our experiment results showed 0.6D.
    - However, for other runs, we can achieve 2D reduction. It exactly showed the instability of pressure cooker., which cannot give us consistent results.
    - We only used the temperature recording device once due to time constrain, and the device is brand new and not used before. We cannot draw conclusion that the device tells the TRUE temperature in ALL runs, as we think something was wrong with pressure cooker in that run.

- We have tried to control everything very consistently, and even for sterilization temperature, we maintained at around +/-0.3°C.
- The intrinsic instability of pressure cooker and imprecision of pressure gauge may give different actual temperature in different runs., even though the reading still shows 123 degree.
  - This explained why different burst open rate occurred in different runs for the "same" condition.
- The Korean Prof will come to Singapore again in Jan and we will have another chance to use the device. We will confirm the result then.

Options with imprecise pressure cooker and pressure gauge

- Change to a new pressure cooker and make sure it is well calibrated before use.
- Change the pressure gauge of the current pressure cooker to a well calibrated one
  - Replace it from the manufacturer
  - Buy a new one from other companies
- Calibrate the current pressure gauge
  - More details on the next slide.
- We don't have any preference to one of methods above. We have to see which one is easier and more feasible to do.
- I really hope Erine can help us on this issue. Thanks so much!

Calibration of Pressure Gauge

- *The Complete Guide to Home Canning* (USDA, 1989) recommended that dial pressure gauges be checked for accuracy each year to ensure that the food is processed safely.
- Our pressure gauge showed higher reading than the actual temperature inside the pressure cooker, which will cause under-processing of food product and thus present a food safety risk.
- Not enough microbial reduction in previous trials was largely contributed by the under-processing.

Dial pressure gauge

- The pressure gauge used on our pressure cooker is a fixed dial gauge.
- This kind of gauge must be calibrated at least once each year to ensure proper and safe functioning.
- The working mechanism of dial pressure gauge is simple.
  - Pressure changes applied to the gauge cause the elastic element to expand to contract.
  - The movement of the element is translated into movement of the pointer through links, levers, and gears.
  - The measurement values of the gauge are read directly on the gauge scale from the position of the pointer

Methods for calibration of pressure gauge

- Send the gauge to manufacturer
- Or use a thermometer that can stand high temperature and stop at the highest temperature in the medium.
  - The mechanism is similar to thermometer for body temperature.
  - Can put it inside the pressure cooker during processing and calibrate several T points from 100 to 126 degree.
- Or remove the gauge from the pressure cooker and mount it along with a U-tube filled with mercury (manometer).
  - determine how high a given pressure reading would force the column of mercury
- Or use a gauge tester, and this method was used in some home pressure cooker workshop.
- Or send to a contracted service company, e.g. Emetrology Pte Ltd.

Future Plan

- Most importantly, we need to have a more stable pressure cooker to further our research.
- The Korean Prof will come back to Singapore in Jan, and he can help us measure the temperature profile again.
- So before he comes,
  - Source for a precise instrument, or calibrate the old one
  - With the new pressure cooker or gauge, we also need to spend some time finding out the correct processing condition, as we still don't know the real processing condition for 123C for 20min.

- Have started shelf life testing at room temperature. It will last for 6 month.
- Modify the formulation
  - Increase protein content
- Modify the processing
  - Will investigate the blanching step, as it causes around 50% vitamin C loss.
  - Examine whether we can remove the blanching step based on nutritional, microbial, sensory views as well as and packaging failure rate.
- Test other nutrients
  - May investigate the B vitamins.

Supplementary: Principles of pressure cooking and commercial retorting

Pressure cooking- venting

- Air trapped in a canner lowers the temperature obtained at 5, 10, or 15 pounds of pressure and results in under processing.
- Dial-gauge canners canners do not vent air during processing. To be safe, all types of pressure canners must be vented 10 minutes before they are pressurized.
- How to vent
  - heat the filled canner with its lid locked into place boils water and generates steam that escapes through the petcock or vent port.
  - When steam first escapes, set a timer for 10 minutes. After venting 10 minutes, close the petcock or place the counterweight or weighted gauge over the vent port to pressurize the canner.

Pressure cooking-release pressure after cooking

- Natural release method:
  - it allows foods to continue cooking while the pressure gradually reduces on its own.
- Cold water release, method
  - it means taking the cooker to the sink and running a stream of cold water over the lid until the pressure drops. Do not run the water directly over the vent or pressure regulator, and do not use this method if you have an electric pressure cooker.
- Quick release method, which is a feature found on some first-generation cookers and all second-generation cookers.
  - This method uses a valve located on the lid to manually release the pressure and takes less time than the natural release method, but longer than the cold water release method.

Weighted-gauge (not in our canner)

- Weighted-gauge models exhaust tiny amounts of air and steam each time their gauge rocks or jiggles during processing.
- They control pressure precisely and need neither watching during processing nor checking for accuracy.
- The sound of the weight rocking or jiggling indicates that the canner is maintaining the recommended pressure.

Commercial retorting

- Parts of a retort
  - steam distribution system
  - cooling water supply
  - a compressed air supply for pressurized cooling
  - valves for venting and draining the retort
  - petcocks for flowing air from the retort

Retorting - Process

- Baskets of cans are placed in the retort and the lid closed.
- With the vent, drain and the bypass to the controller valves open, the venting sequence to remove the air from in-between the cans and baskets is started by introducing steam until the temperature in the retort is about 100 $^\circ$C. The drain is then closed.
- Venting continues for the prescribed time, and the vent valve is then closed.
- The temperature is brought up to about 5 $^\circ$C below the required processing temperature, and the steam bypass valve closed.
- The retort is allowed to attain the scheduled temperature using the controller.
- When the time for processing is complete, the steam valve is closed and the cooling cycle started.
- Compressed air is introduced to balance the pressure inside the can.
- While continuing to counter-balance the pressure, water is allowed to run through the overflow/vent valve until cooling is completed, i.e. until the cans have reached a temperature of about 40 $^\circ$C.
- When the pressure is atmospheric the lid, which should be fitted with a safety bolt, is opened and the baskets removed.

Retorting - Internal pressure

- When a hermetically sealed container of food is heated the internal pressure rises due to increasing vapor pressure of the liquid portion; air and other gases in the headspace expanding; and expansion of the food mass.
- The rise is partially counter-balanced, in the case of a can, by expansion of the can and the outward movement of the can ends, which are designed with expansion rings.
- The situation is different with semi-rigid packaging materials that have only a limited elastic expansion, which can damage the material or the seams.

Retorting – Air removal

- Important to eliminate the air after filling
- Previously by clinching the lid on the can and "exhausting" the can by heating and then seaming
- Now by blowing steam across the can before seaming, in a process known as steam flow closing.
- The removal of air from the headspace also reduces the amount of oxygen in the can and reduces the likelihood of product–container interactions.

Retorting - Cooling

- For all types of sealed container the vapor pressure of the liquid portion of the components increases with increasing temperature, so that as the can is heated externally the internal pressure rises.
- the internal pressure in rigid containers is counterbalanced to a certain extent by the pressure of the steam or hot water in the heating stage. However, at the end of the heating stage, if the pressure on the can is suddenly released while still hot, there is a danger of can distortion, known as peaking, which may weaken the seam or cause the can to jam in a valve or a subsequent process, such as labeling. The effect is more serious with the larger-diameter cans, and it is usual to prevent such distortion by superimposing a pressure during the cooling cycle, for sufficient time for the can to have cooled and the internal pressure to have reduced to a comfortable level

- While steam retorting is convenient for many types of container, several types of plastic container and pouch require overpressure to maintain the integrity of the packaging material. This may be achieved using steam–air mixtures or recirculating pressurized hot water. Rotating mixer blades are used to circulate the steam and to ensure that the mixture is kept uniform; this is particularly important in order to maintain a uniform temperature during processing.
- the seams of a can are vulnerable to ingress of spoilage microorganisms at the cooling stage, when a vacuum is developing in the headspace of the can. It is, therefore, necessary to chlorinate cooling water so that it has a residual of 1 ppm free chlorine before it is used.

Retorting – heating medium

- Condensing saturated steam
  - very high surface heat-transfer coefficient
  - a negligible resistance to heating the surface of the can. The surface of the can is therefore immediately at the temperature of the condensing steam.
- With the requirements for other types of packaging material, steam–air mixtures and pressurized water systems are now commonly in use.
  - These do not have the properties of condensing steam and require extra controls to safeguard the process.
  - The heat-transfer coefficients are much lower; consequently, there is an appreciable resistance to heat transfer at the surface of the container. This resistance must be taken into account in determining the process requirements.
- It was reported that steam–air mixtures heated more slowly and less uniformly than saturated steam at the same temperature. This was directly attributed to a stagnant film of air that was displaced during condensation and formed near the surface of the container.
- It was also shown that the effect of steam– air mixtures was far greater with convection- than with conduction-heating packs

Retorting – heat transfer

- Solid-packed foods, in which there is essentially no product movement within the container, even when agitated, heat largely by conduction heat transfer.
- Because of the lack of product movement and the low thermal diffusivity of most foods, these products heat very slowly and exhibit a non-uniform temperature distribution during heating and cooling caused by the temperature gradient between the can wall and geometric center.
- These foods are usually processed in still cook or continuous hydrostatic retorts that provide no mechanical agitation.