A Workcell Approach to High Volume Veterinary Fecal Parasite Testing

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-- Complete sample processing from collection to ready-to-read slide
-- High throughput (400-500/day/technician); Rapid TAT (under 10 minutes)

As evidence continues to mount that simple gravity or "passive" flotation is a suboptimal procedure for ova detection, the market for commercial veterinary fecal parasite testing has expanded considerably. Many clinics, faced with a need to abandon the popular bench top gravity device, have opted to send fecals out to a reference laboratory rather than adopt the recommended but more complicated and messy standard centrifugal flotation method. Today there are several multi-national veterinary reference laboratory networks with dozens of facilities performing an estimated seven to eight million fecal parasite tests annually.

The traditional approach to high volume fecal parasite testing is a "batch and queue" processing scheme. That is, the sequential steps of the test method are done in a batch-wise manner and passed on to the next worker. The steps involved in the processing of fecal samples by the centrifugal method in a high volume laboratory are as follows:

1. **Collect 1-2 grams of test material from patient sample**
   - Open container, remove 1-2 grams of sample with a wood spoon, close container.
2. **Mix well with 5 mL of flotation fluid**
   - Usually done in Dixie cup with wood spoon. Flotation fluid is usually $ZnS0_4$ or sucrose.
3. **Filter sample to remove particles and debris**
   - Slurry poured through gauze into a second Dixie cup. Debris on gauze is mashed with spoon to obtain maximum sample. Dispose of material after next step.
4. **Pour into 15 mL tube; add flotation fluid**
   - Pour prepared sample into tube, add flotation fluid to about 1 cm of brim.
5. **Centrifuge for 7-10 min. at 850-1000 xg**
   - Usually done in a large capacity swing out centrifuge in batches of 20 or more. Two steps involved – loading and later unloading centrifuge.
6. **Add flotation fluid to form slight meniscus**
   - Carefully drip fluid down sidewall of tube with dropper to avoid re-suspending ova. This and next steps are done in the idle centrifuge or tubes are transferred to the bench.
7. **Place a coverslip atop each tube**
   - Surface of fluid must be in contact with coverslip; add more fluid and re-settle if needed.
8. **After 5-10 minutes, lift up coverslip and transfer to microscope slide**
   - A 20 place slide mailing tray is usually placed near tubes to allow easy transfer of coverslips. Completed trays are delivered to microscope stations for reading. Used centrifuge tubes are disposed prior to next batch.

There are additional steps for sample identification which are obviously critical to a laboratory performing hundreds or thousands of tests per day. Usually a fecal sample container is bar coded at accessioning and transferred to the laboratory. The bar code label contains customer and test information as well as a human-readable accession number. Large laboratories employ varying strategies for sample identification ranging from application of bar codes to centrifuge tubes and slides right in the workstation, to preparation of lists and matching to numbered slides. Ultimately, the bar-coded or numbered slide is used by the reading technician to enter findings into the database; results are often reported to the ordering veterinarian on-line.

Pitfalls of Batch Processing

As in most production environments, multi-step batch processing in the high volume laboratory is subject to a number of inefficiencies and pitfalls. Bottlenecks between processing steps are inevitable resulting in workers either waiting for samples or racing to catch up. Time and space is wasted transferring racks or trays of samples between workstations. And in the case of the fecal parasite lab, the sample can become over-exposed to $ZnSO_4$ or sucrose while waiting in queue resulting in degradation of some parasite structures such as Giardia cysts.

Batch processing also limits the laboratory's ability to accommodate swings in testing volume as are common with veterinary reference labs. Work assignments need to be reallocated by giving technicians more steps to perform or dividing excess work between technicians. Either way, labor scheduling can be a daunting task and the normal work routine - and often the technicians themselves - become upset.

Because of the long preparation time resulting from large batch processing, test turnaround time (TAT) can be anywhere from 30 minutes to as long as an hour or more if prepared slides stand if queue in front of slide readers. This limits the lab's ability to report results quickly and to handle retest requests in an efficient and responsive manner.

Lean Processing Alternative

The primary goal of this study is to determine if a "lean processing" or a workcell approach to high volume fecal parasite testing could be a viable alternative to batch processing. We used the StatSpin OvaTube from IRIS Sample Processing (Westwood, MA) as a processing aid (fig. 1).

Fig. 1 *The StatSpin OvaTube centrifugal flotation device for ova and parasite detection.*

The OvaTube is a disposable device that was originally developed to meet the needs of in-clinic fecal testing by the centrifugal method, but the device offers a number of processing innovations that are advantageous in a reference lab environment as well. The Mixer component (fig. 2) allows the technician to easily core a 1 gram sample from the patient container and thoroughly mix the sample directly in the centrifuge tube using a simple bulb squeezing action. The integral Filter (fig. 3) completely eliminates the time consuming and objectionable gauze filtration step by preventing hair, seeds and other "floaters" that are present in the sample from rising with the ova during centrifugation.

Finally, the device has a twist mechanism that elevates fluid in the tube from the bottom thereby minimizing disruption and re-suspension of ova at the surface. This feature simplifies and accelerates the coverslip step and reduces required settling time from 5-10 minutes to only three minutes. Studies [1,2] demonstrate that OvaTube results are substantially equivalent to the "gold standard" centrifugal flotation method.

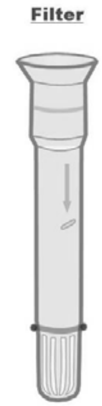


Fig. 2 *OvaTube sample collector and mixer.*
Fig. 3 *OvaTube filter.*

Time and Workflow Study

A time-motion study was devised to determine the suitability of the OvaTube device to lean processing in a high test volume environment and to quantify the potential labor savings that could be achieved vs. large batch processing. The objectives of the study included:

- To determine the smallest OvaTube batch size to process the largest number of samples per hour. Since centrifugation is by definition a batch process; the authors hypothesized that a small batch size would result in more efficient utilization of equipment and a net production increase over large batch processing, in keeping with the principles of lean processing.
- To critically observe all OvaTube processing steps for the purpose of identifying additional labor saving opportunities.
- To design an optimum workflow plan and equipment layout that would minimize potential bottlenecks, improve space utilization and streamline the testing process while reducing labor cost per test.

Methods

The study was conducted at the IRIS Sample Processing R&D laboratory in Westwood MA. Three individuals participated in the test – a laboratory supervisor, a quality control technician and an office worker – to provide the range of skill sets and laboratory experience that might be encountered in the workplace. Each participant was trained on the particular processing task to be performed and allowed to practice the procedure before data was collected. Simulated samples (peanut butter) were used and bar code scanning and labeling were also simulated by applying peel-off sheet labels to tubes and microscope slides.

Participants were instructed not to rush any task but rather work at a steady pace as they might do in a production environment. For each OvaTube processing step, study participants performed the tasks involved twice, first for a batch of six samples, then for a batch of eight samples and finally for a batch of ten samples. The resulting six data points for each of the three batch sizes were averaged to obtain the required time for each OvaTube processing step. For the standard centrifugal method, participants performed the tasks involved in each processing step three times with a batch size of twenty samples. The nine data points for each step were averaged to obtain time required for each processing step.

Finally, a laboratory technician was observed for two hours performing the OvaTube method in a continuous manner to determine the operator's ability to maintain an efficient work flow and to determine overall turnaround time and throughput.

Results

The standard centrifugal flotation method [3,4] is a labor-intensive, multi-step process used to prepare slides for microscopic examination of intestinal parasite ova and cysts. In a large veterinary reference laboratory, these processing steps are typically divided among several technicians who perform assigned tasks in batches defined by the capacity of the centrifuge used, usually about 20 or more samples/run. Workers complete the steps in a batch, pass the completed samples to the next worker in the production line, then begin the next batch. Fig. 4 shows the discrete steps involved in the standard centrifugal flotation method and the time required for each based on the results of this study. It should be noted that the resulting total processing time may be a "best case scenario" since the time study did not account for additional time that would be required to transfer samples from one workstation to the next, or delays resulting from bottlenecks between workstations.

The StatSpin OvaTube simplifies sample collection and mixing, eliminates manual filtration to remove unwanted "floaters" such as grass or hair, and reduces

Fig 4: **Time Study Using the Standard Centrifugal Method for O&P Testing**

Processing Step	Twenty Samples
Get patient sample containers from accessioning cart.	25 seconds
Scan samples and apply bar codes to tubes and slides.	154 seconds
Dispense flotation fluid into Dixie cup. Open patient sample and remove approx. 1 gram of stool; mix with fluid in Dixie cup.	450 seconds
Sample in Dixie cup is strained thru gauze and mashed with spoon. Throw spoon and original Dixie cup and gauze away.	320 seconds
Dixie cup with stool is squeezed and slurry is poured into 15 ml tube, discard Dixie cup.	120 seconds
Fill up the 15ml tube with flotation fluid to about 1 cm of brim.	120 seconds
Tubes are transferred and placed in centrifuge - 20 samples.	300 seconds
Move patient samples to finished cart.	25 seconds
Place microscope slides in tray.	24 seconds
Open centrifuge and pipette flotation fluid to top off each tube by running the fluid down the side of the tubes.	200 seconds
Place coverslips on top of tubes.	80 seconds
Remove coverslip and place on microscope slide.	60 seconds
Dispose centrifuge tubes.	25 seconds
Total of Processing Step Times	**1903 seconds (31 min 43 sec)**
Number of Samples Per Hour of Labor	**37**

Note: Above time study does not include time required to transfer samples between workstations or possible delays resulting from bottlenecks between workstations.

the number of sample transfer steps required by the standard centrifugal method. As a result, the individual processing steps for a small batch of samples can be performed in a serial manner by a single technician while the centrifuge is separating samples of the previous batch.

provide a significant reduction in required labor when compared to the standard centrifugal flotation method. Without considering the wasted time transferring samples between workstations and bottleneck delays which are inherent to the conventional batch and

Fig. 5: **Time Study Using OvaTube Centrifugal Method for O&P Testing**

Processing Step	Six Samples	Eight Samples	Ten Samples
Get patient samples from accessioning cart.	15 seconds	17 seconds	19 seconds
Place OT tubes in rack.	8 seconds	11 seconds	14 seconds
Place microscopes slides in tray.	13 seconds	17 seconds	20 seconds
Scan patient samples and apply bar code labels to tubes and slides.	67 seconds	85 seconds	102 seconds
Fill OT tubes to the fill line with flotation fluid.	25 seconds	31 seconds	37 seconds
Core sample and mix in corresponding OT tube, Dispose mixer.	90 seconds	120 seconds	150 seconds
Move patient samples to finished cart.	15 seconds	17 seconds	19 seconds
Place OT filters atop OT tubes.	40 seconds	41 seconds	54 seconds
Top off filters with flotation fluid.	29 seconds	41 seconds	65 seconds
Transfer OT to centrifuge.	16 seconds	19 seconds	21 seconds
Remove OT from centrifuge to rack.	24 seconds	28 seconds	32 seconds
Place coverslips atop OvaTubes.	13 seconds	20 seconds	26 seconds
Twist each OT so that the fluid touches the coverslip.	15 seconds	19 seconds	21 seconds
Lift up coverslips and transfer to corresponding microscope slides.	12 seconds	16 seconds	21 seconds
Twist and remove OT from rack and dispose.	6 seconds	8 seconds	10 seconds
Total of Processing Step Times	**388 seconds (6 min 28 sec)**	**490 seconds (8 min 10 sec)**	**611 seconds (10 min 11 sec)**
Number of Samples Per Hour of Labor	**55.7**	**58.8**	**58.9**

Early in the time and motion study of the OvaTube method, participants expressed a degree of difficulty with two of the processing steps – 1) adding flotation fluid to the fill line mark on the tubes and 2) twisting the OvaTube following centrifugation to elevate the surface of the fluid to the coverslip. A bottle-top reagent dispenser (Fisher Scientific Cat. No. 13-687-261) was added to the workstation to allow easy and precise addition of 5 mL of fluid without having to check the fill line. To simplify the twist step, a custom rack was created that supports the OvaTube near the top opening thereby allowing the tube to be twisted at the bottom with one hand. The special rack (Fig. 5) also simplified the process of lifting coverslips for placement on slides and removing tubes for disposal. Retesting with these workcell improvements in place showed a 4-5 second per sample reduction in processing time or nearly 40 seconds for an eight sample batch.

As can be seen in Figure 5, the OvaTube device can

queue processing scheme, the OvaTube workcell can improve worker productivity by 66% in a step by step comparison of processing times. More importantly, the OvaTube method allows all of the processing steps to be performed by a single technician resulting in a more efficient, continuous workflow in contrast to large batch processing.

While there was a slight processing advantage to a batch size of ten OvaTubes, the batch size of eight was selected as optimum due to the low cost and compact size of common eight-place fixed angle centrifuges. Figure 6 shows the average of workflow cycle times over a two hour period for an OvaTube workcell with an eight place centrifuge. In this part of the study, tubes were pre-racked and slides were preloaded into trays as may be the case in a large lab to increase efficiency. In addition, time for bar-coding or marking of tubes or slides was not considered as laboratories use many different approaches to sample identification.

The eight piece batch size of the OvaTube workcell and the exclusive three minute settle time allow virtually all of the labor steps to be performed during the five minute centrifugation of the previous batch. It was observed in continuous operation of the workcell that the centrifuge was rarely idle for more than 15 second (not including the 1 minute 10 seconds of loading and unloading the centrifuge).

found that one technician can routinely process 55 - 60 samples per hour using the OvaTube system and an inexpensive 8-place fixed angle centrifuge; peak production rates of 60 - 65 samples per hour can be achieved by a highly competent technician. One workcell on two shifts can accommodate nearly a thousand tests per day; two workcells with 5 FTE's over three shifts can do well over two-thousand tests per day with greater workflow efficiency and much faster turnaround compared to large batch processing.

Fig. 6: **Average Cycle Times Using OvaTube Workcell with 8-Place Centrifuge**

Processing Step	Task Time (seconds)	Cumulative Time (min:sec)
1. Unload centrifuge, place tubes in rack	**27**	**0:27**
2. Load centrifuge, set for 5 min. spin	**16**	**0:43**
3. Fill 8 tubes in preloaded rack with 5 mL each	**48**	**1:31**
4. Put coverslips atop tubes in rack	**24**	**1:55**
5. Twist tubes in rack for fluid contact with coverslips	**22**	**2:17**
6. Open sample container, core sample, mix, install filter, top off with fluid, reseal container (repeat for each of eight samples)	**259**	**6:36**
7. Transfer coverslips to microscope slides	**14**	**6:50**
8. Dispose tubes from rack	**18**	**7:08**
Total Cycle Time	**428**	**7:08**
Number of Samples Per Hour of Labor at Peak*	**67 samples/hr**	

Note: Cycles performed using pre-racked tubes and slide pre-loaded in trays.
* Does not include time for bar coding of samples. Assuming 7-10 seconds per sample for labeling, throughput would be reduced to 57 – 60 samples per hour.

As can be seen in Figure 6, the average cycle time required for an OvaTube workcell operator to prepare a batch of eight slides is slightly over seven minutes, or a production rate of 67 samples per hour. If 7-10 seconds are added for each sample for bar coding or marking of slides, TAT remains well under 10 minutes and throughput becomes 57 to 60 samples per hour, still a significant improvement over large batch processing.

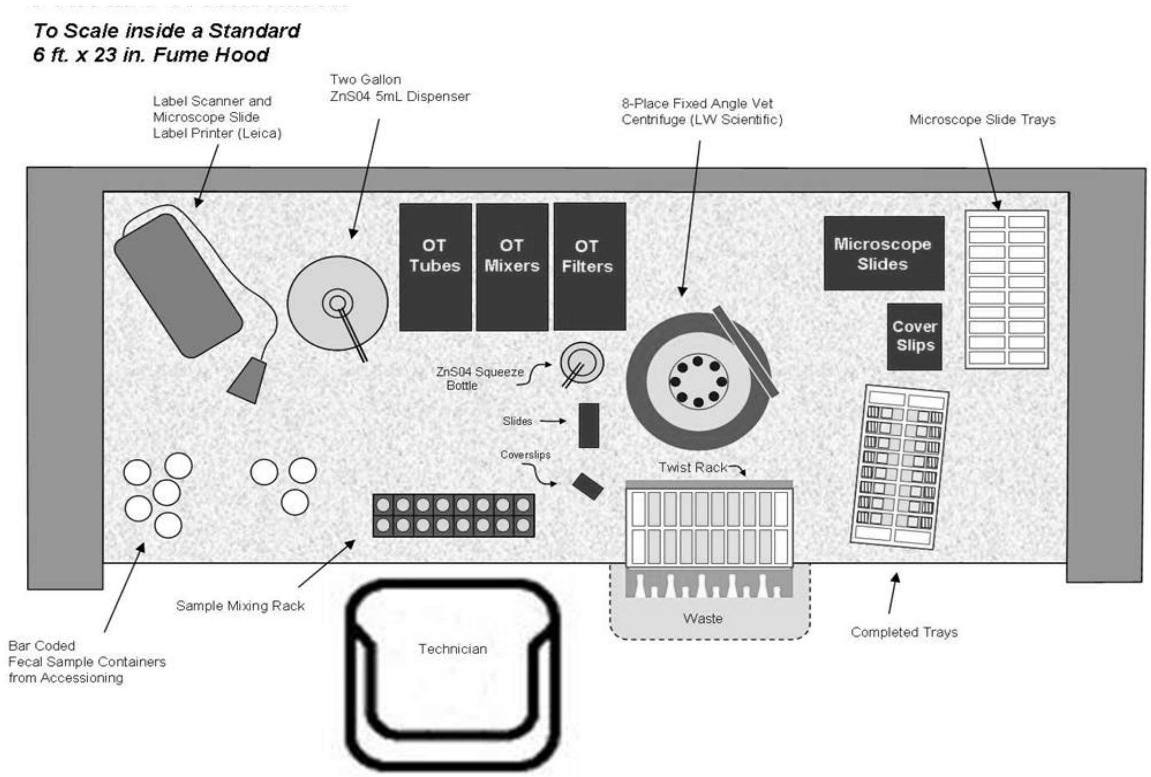
Discussion and Conclusions

This workflow time study for fecal parasite testing has resulted in the development of a compact workcell that can allow a <u>single-technician</u> to perform all sample prep steps for 400-450 fecal parasite tests per day in a Veterinary reference lab environment (Fig.7). It was

Since all sample prep steps are performed in serial manner by one person, there is no need to transfer and queue completed samples for the next work station and the space required for processing is significantly reduced. The entire workcell can fit easily within a standard 6 ft. fume hood for near-odor free operation.

Work assignments are precise and predictable. To accommodate a sudden increase in test volume such as the result of a marketing promotion, incremental workcell hours are added rather than having to divide added batch work among a pool of assigned technicians. If sample volume decreases, workcell hours are decreased rather than having to combine workstation tasks and disrupt normal work flow.

Fig. 7: **OvaTube Workstation**



Typical OvaTube Workcell equipment layout

The eight piece flow of the workcell means that a sample can fully processed and ready to read in well under 10 minutes in contrast to 30 minutes or more with batch processing. Delicate structures such as Giardia cysts have less exposure to $ZnS0_4$ or sucrose which can shrink the objects to an unrecognizable state under the microscope[5]. The workcell also serves to enhance the efficiency of the downstream slide reading process by supplying a constant flow of slides – reading technicians are never waiting for slides or rushing to keep up with the queue as can happen with batch processing.

The OvaTube Workcell lends itself to bar code labeling and error free sample processing. The workflow study allotted sufficient time to scan patient sample containers, and to print and apply labels to both centrifuge tubes and microscope slides. The small eight piece batch size also enhances the technician’s ability to properly organize samples and maintain positive sample identification throughout the process.

The OvaTube Workcell provides large volume veterinary fecal parasite testing laboratories with the opportunity to substantially reduce labor costs, eliminate bottlenecks, reduce space requirements and better manage cost per test under a variety of test volume requirements. The workcell can also provide technicians and other nearby workers with a cleaner, neater and less odiferous work environment.

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