Obstacle in a funnel

Problem 16.

- Granular material is flowing out of a vessel through a funnel. Investigate if it is possible to increase the outflow by putting an obstacle above the outlet pipe?

Experiment

- Achieveing effect
- Parameters:
  - Flow rate
  - Obstacle height
  - Obstacle shape and diameter
  - Granular material

Experiment cont.

- Achieveing the effect:

  When obstacle is placed on distinct height above funnel outlet flow rate of the granular material is considerably increased (near 20%)!

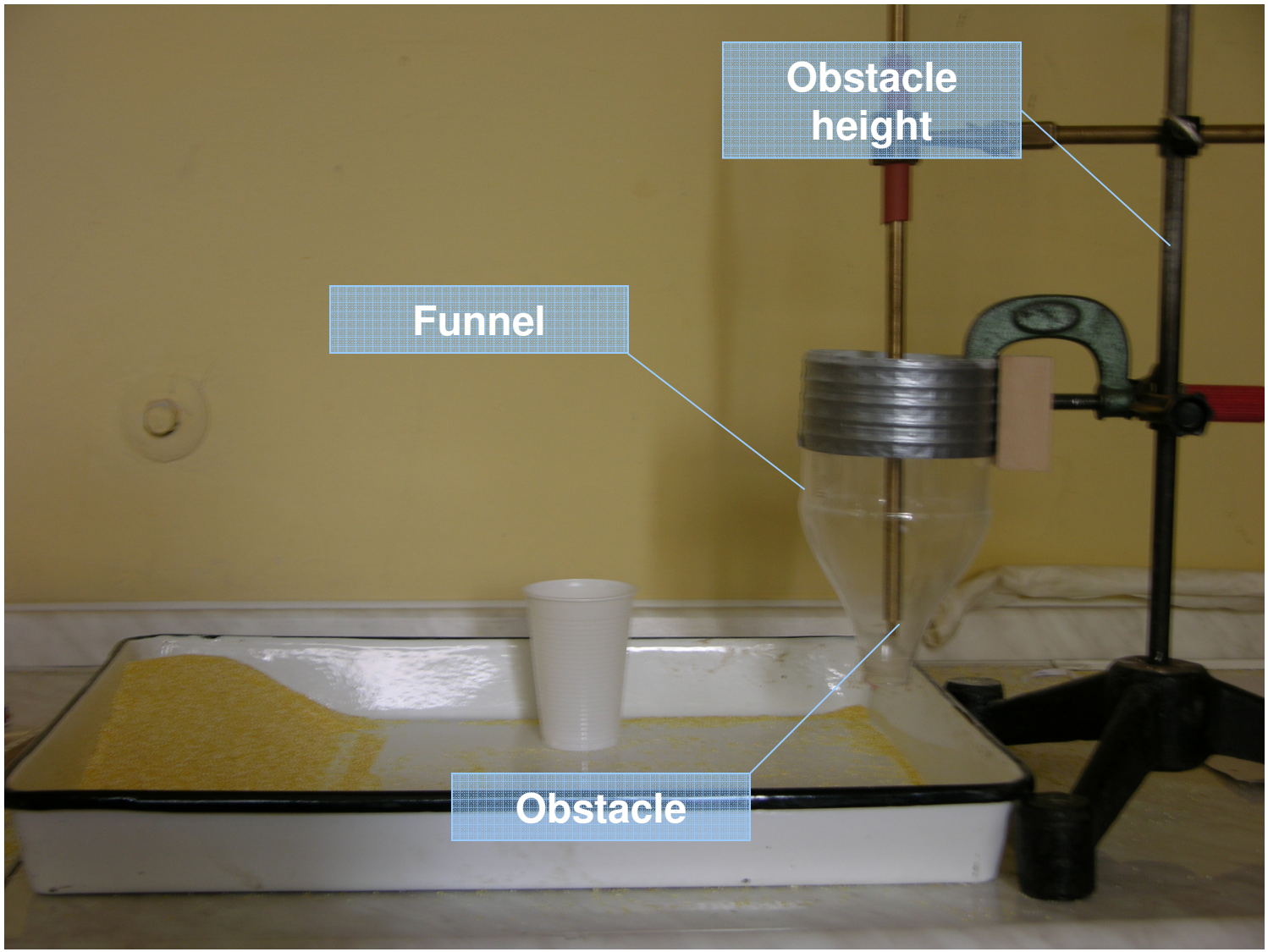
- Conducting the experiment:

  - the same volume of the granular is always used

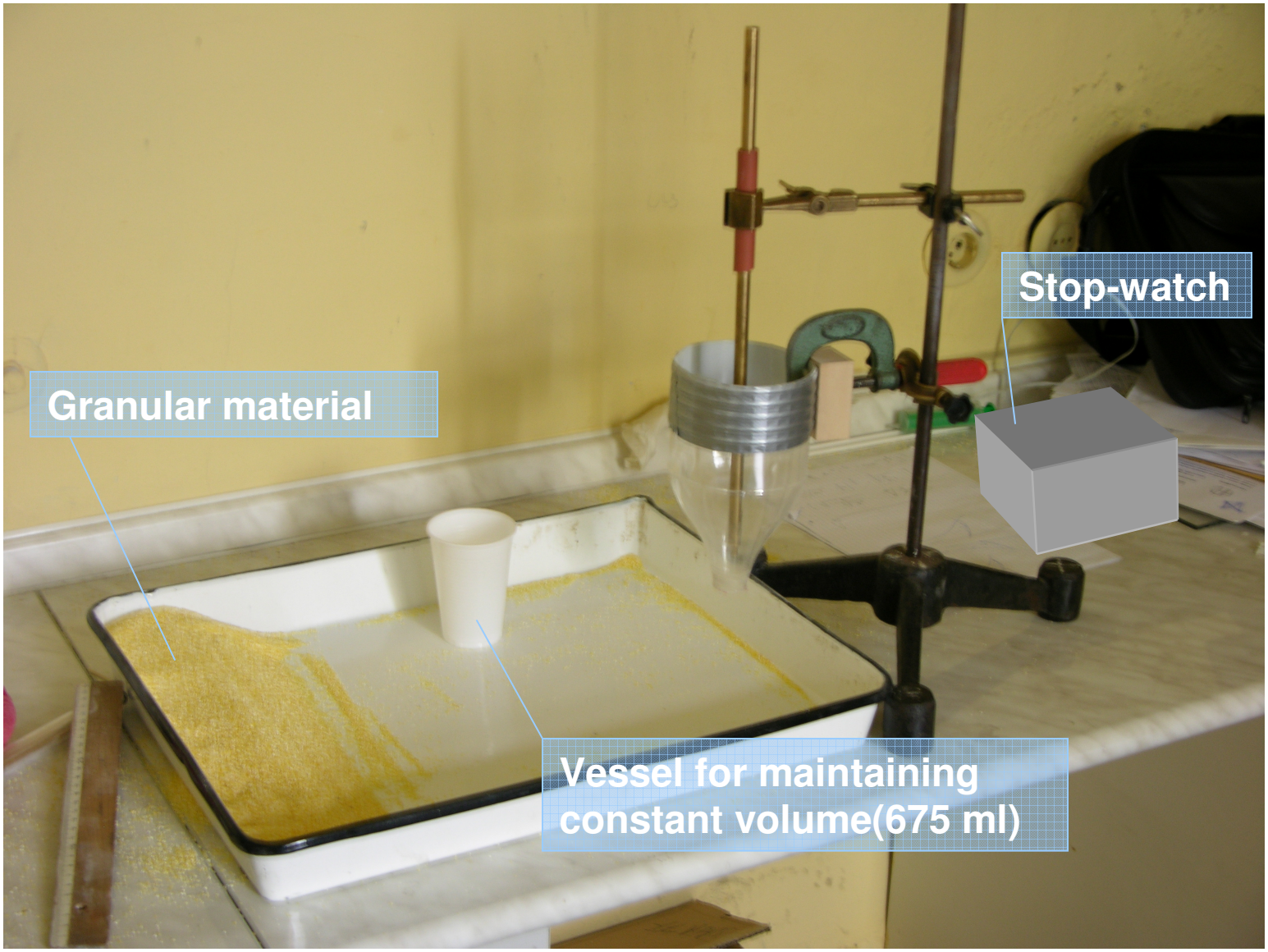
  - to determine the flow rate through a funnel we had to measure the time needed for the granular to flow out of a funnel

  - obstacle height was varied

Experimental setup



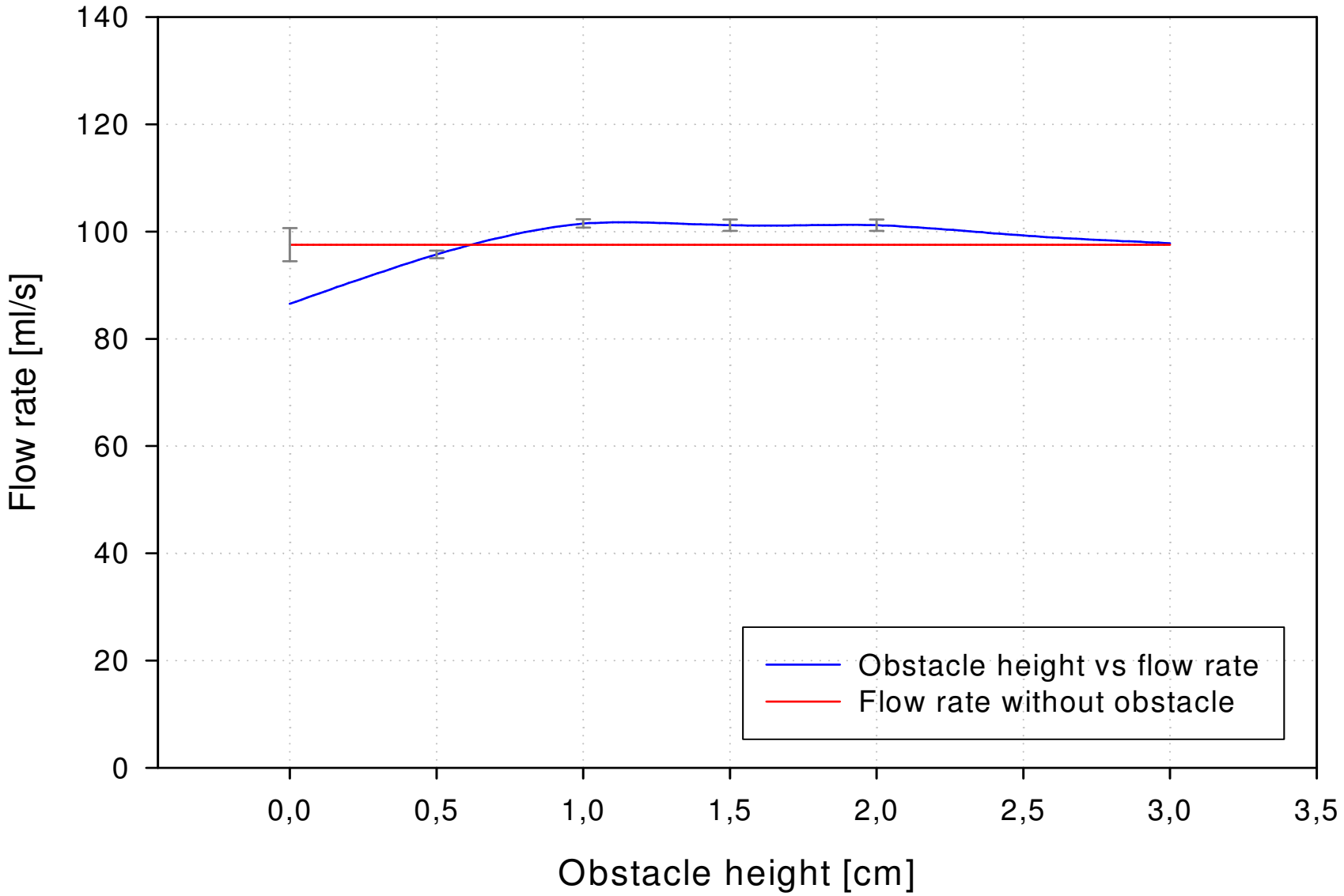
Experimental setup cont.



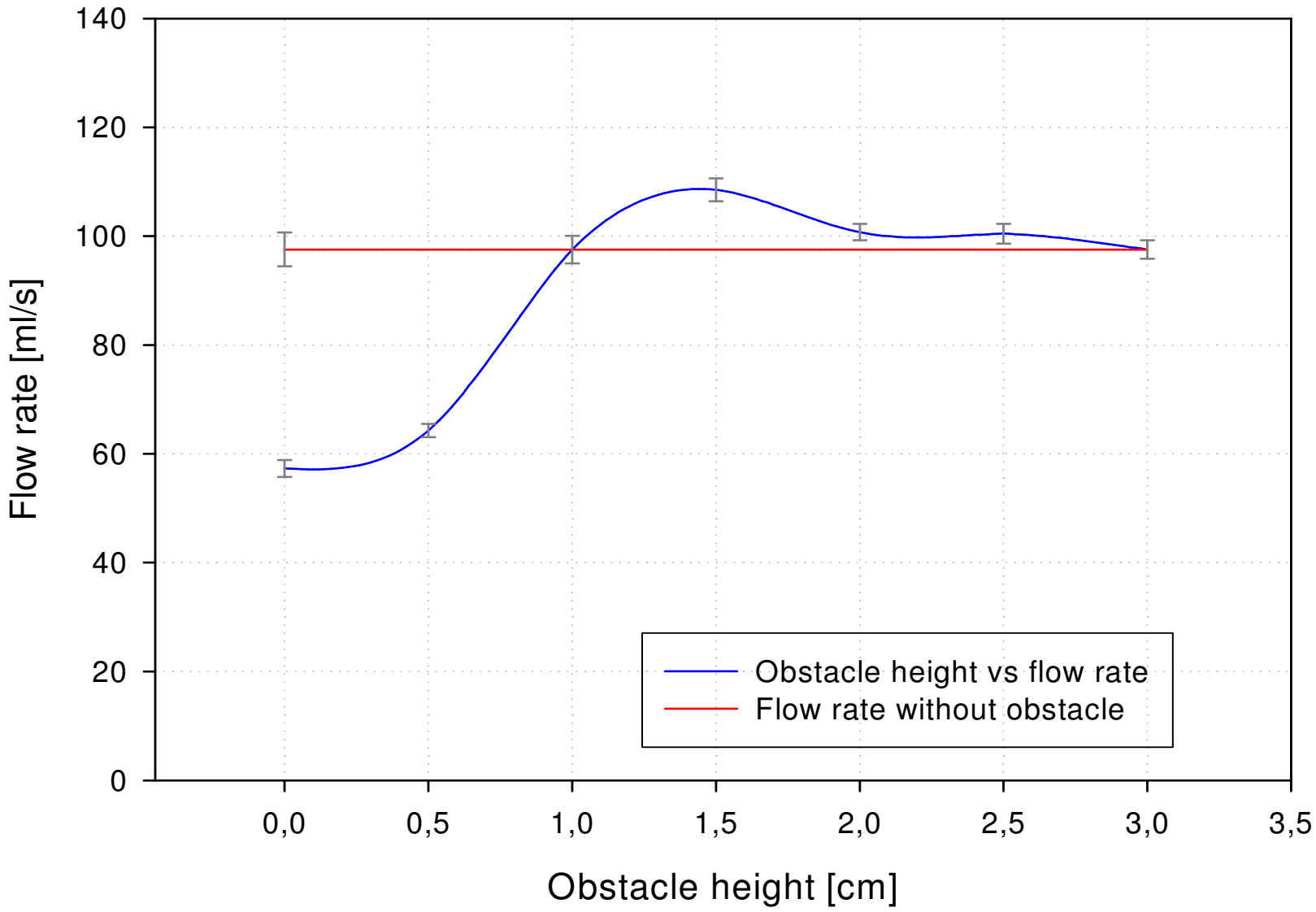
Measurement

- Flow rate dependence on obstacle height
- Multiple repetition of measurement to determine the standard error
- Flow rate increase dependence on obstacle diameter

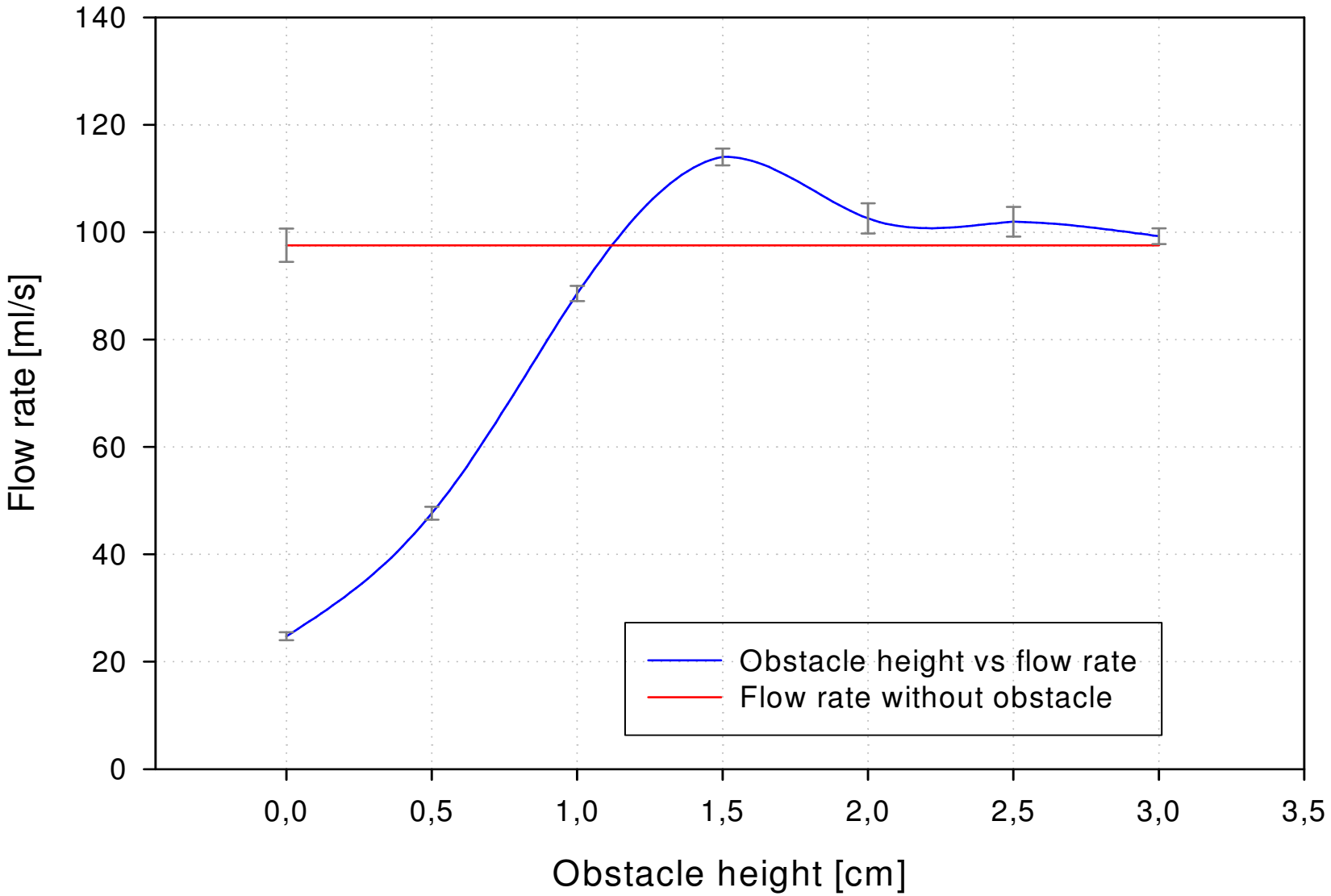
Polenta (Obstacle - diameter 5 mm)



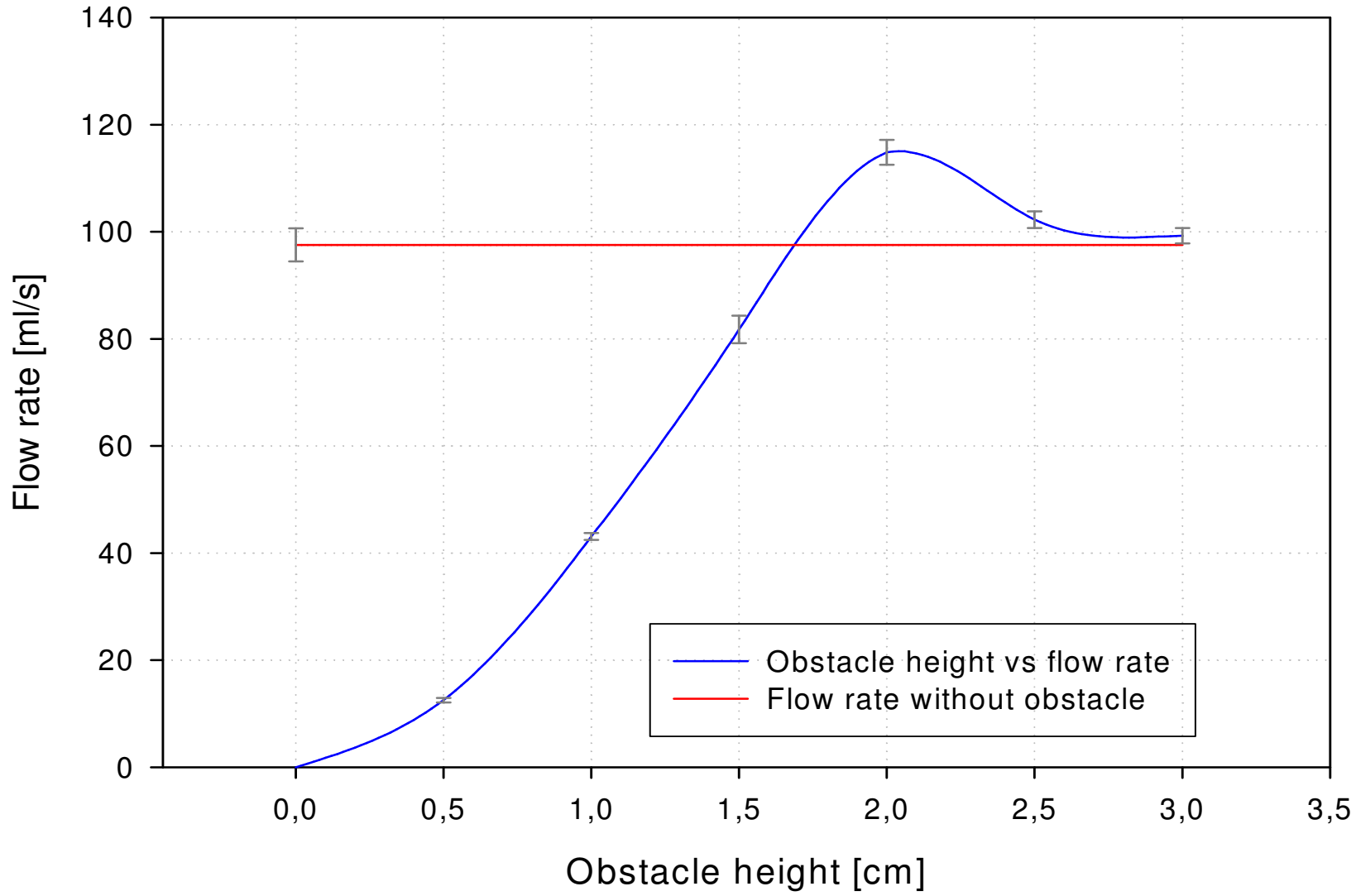
Polenta (Obstacle - Cylinder 10 mm)



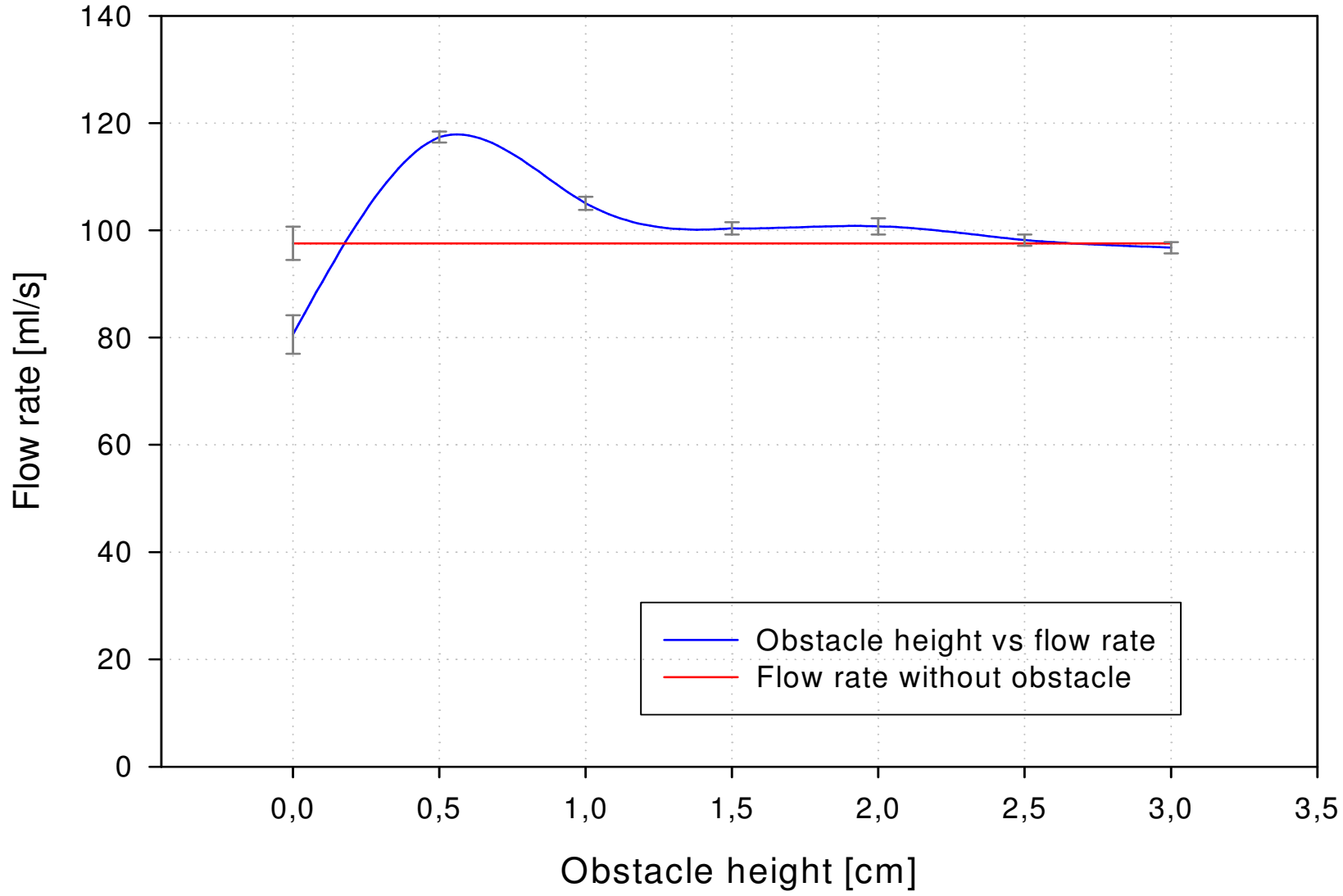
Polenta (Obstacle - Cylinder 15 mm)



Polenta (Obstacle - Cylinder 20 mm)



Polenta (Obstacle - Sphere 15 mm)



Why does the flow rate increase?

$$q \approx vA$$

q- Flow rate

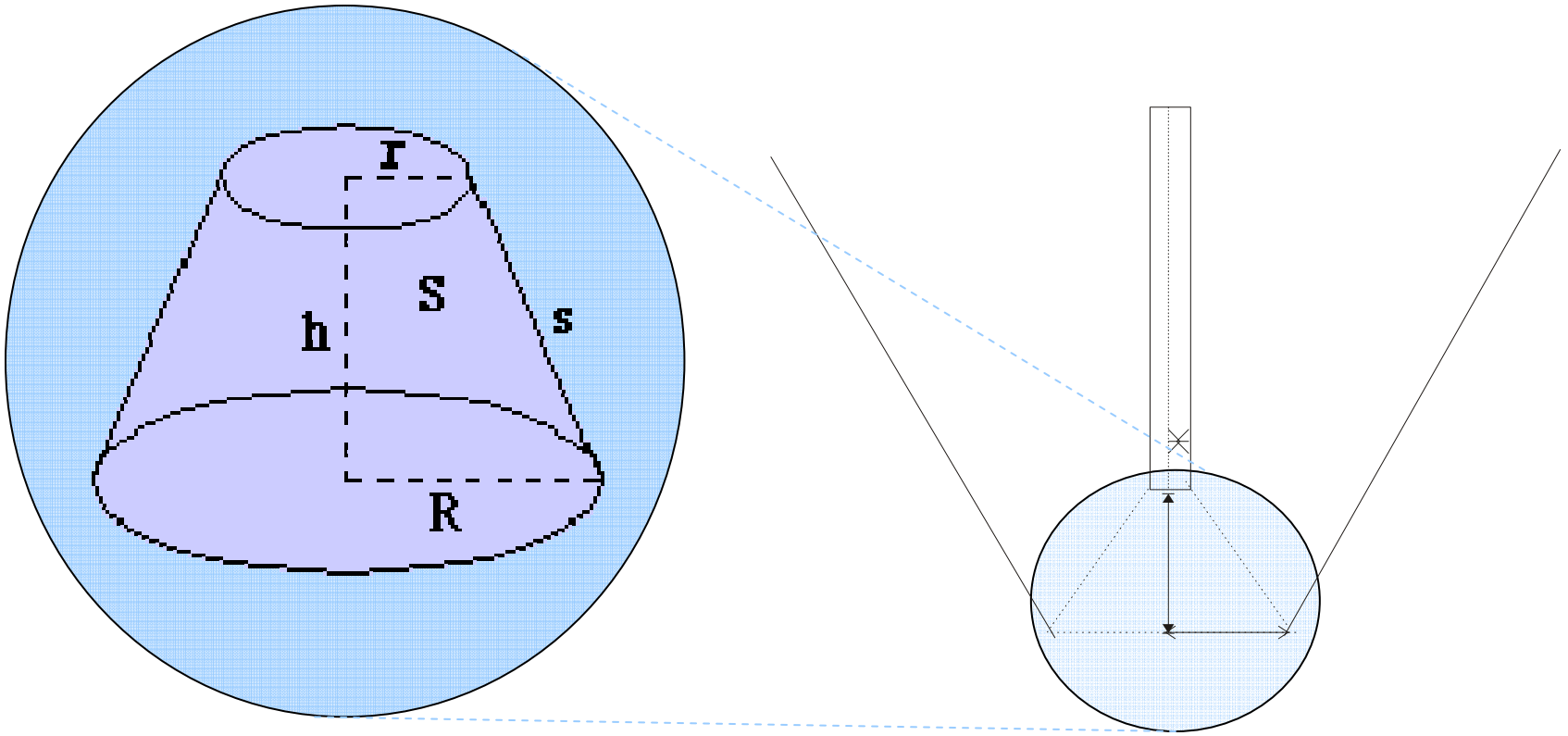
v- Granular streaming speed

A- Flow area

As the streaming speed is nearly constant we can also say:

$$q \propto A$$

Funnel outlet and top of obstacle form frustum of cone whose lateral surface area acts as the flow area



$$A = \pi(r + R)s$$

Inserting previous area into flow equation we get the following flow rate dependence on height and diameter of the obstacle.

$$q \approx v(r+R)\sqrt{h^2+R^2}$$

R - Funnel outlet diameter

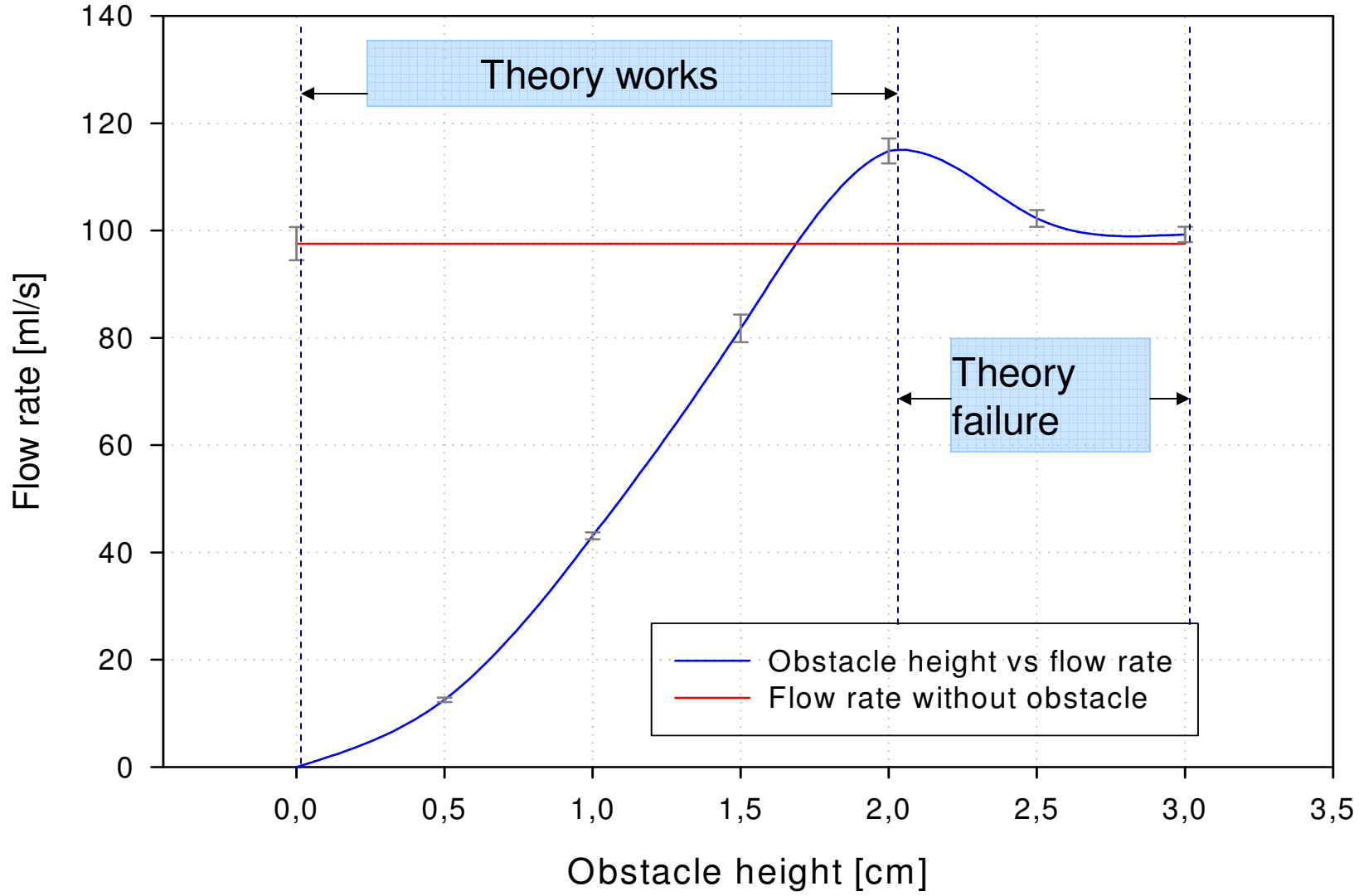
r - Obstacle diameter

q - Flowrate

h - Obstacle height

v - Streaming speed

Polenta (Obstacle - Cylinder 20 mm)



Further flow behavior

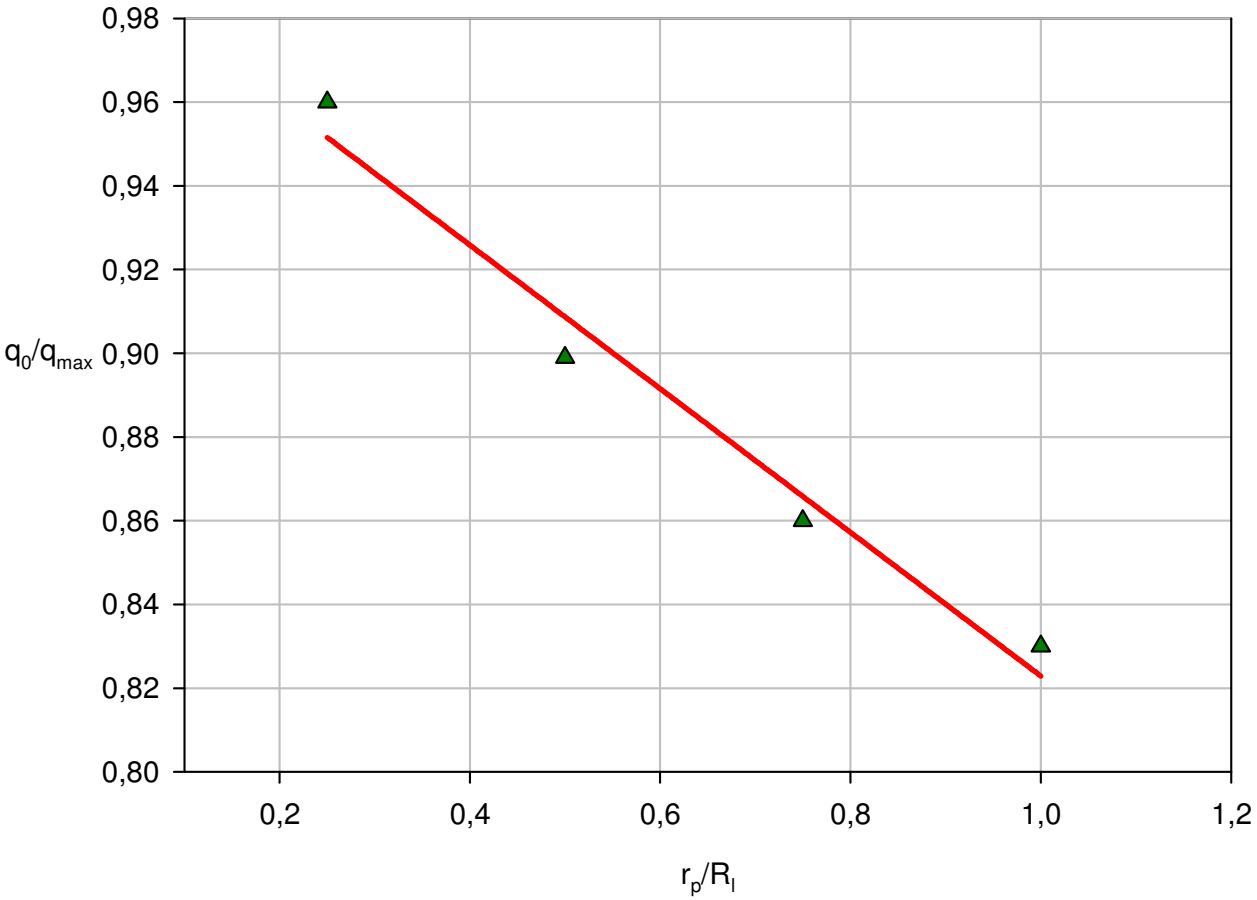
- We can see from measurements :

  - Equation can be fitted to the height close to the obstacle's diameter

  - After that height flow rate increase effect is drowned by collisions between granular particles passing through outlet and the flow rate decreases

  - flow rate depends on the obstacle diameter, so, the larger the diameter of obstacle, the greater the rate increase

What obstacle should be used?



As can be seen from flow rate dependence on the obstacle diameter a wider obstacle should be used if we want to get a larger increase of flow rate

Conclusions...

- We determined the flow rate dependence on:

  - obstacle height
  - obstacle diameter
  - obstacle shape

The wider the obstacle used the bigger the increase

Spherically shaped obstacle gives greatest performance !

Possible inrease up to 20 % !