The coefficient of friction of individual potatoes and various handling materials – Short communication

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Abstract

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The dynamic coefficient of friction of single potatoes was determined on mild steel, rubber and plastic, for tubers in each of four conditions: dry and dirty, wet and dirty, clean and wet and clean and dry. Steel had the lowest overall mean coefficient of friction. The highest value was recorded for plastic, but this material also had the largest coefficient of variation. Overall, rubber was considered to be the most suitable all-condition material for tubers in a range of conditions.

Keywords: handling equipment; machinery; potato damage; surfaces

A wide range of materials are used for potato handling equipment (Bishop, Garlick 1998), those most commonly used being steel, plastic and rubber (BPC 2001). Tuber behaviour on these will depend on the type of surface, their condition and the coefficient of friction (COF or μ) between the two contact surfaces. COF is determined by the load, the independence of the relative surface areas, the sliding velocity and the nature of the contact materials (Mohsenin 1965). This latter aspect will be influenced by the degree of asperity of each surface, the resistance of each surface and its asperity to deformation, the adhesive forces in operation between the two surfaces, and the actual contact area of the asperities.

The objective of this work was to evaluate the differences in COF for different materials and different levels of cleanliness and moisture surface state of single potatoes. Knowledge of these interactions may be of interest to designers and users of handling machinery, to improve efficiency of operation and help prevent damage (Mohsenin 1965; Bouman 1995; Mathew, Hyde 1997).

MATERIAL AND METHODS

Equipment (Fig. 1) was constructed to weigh a randomly orientated and reposed individual tuber which could be deposited via a solenoid-actuated pivot and ramp mechanism onto a vibration-dampened circular measurement table (diameter 360 mm). The table was direct driven by a single phase electric motor and variator unit and rotated at 10 ± 0.5 revolutions/min. The upper contact surface of the table could be changed for testing purposes, the materials used being mild steel [BS (British Standard) surface grade 43A, gauge 4.75 mm], rubber (surface specification 250/2.2 + 1.5, 5.57 mm) and plastic (surface specification PVG. BS.Xquad., 6.20 mm), the latter being a 4-ply PVC material commonly used for agricultural

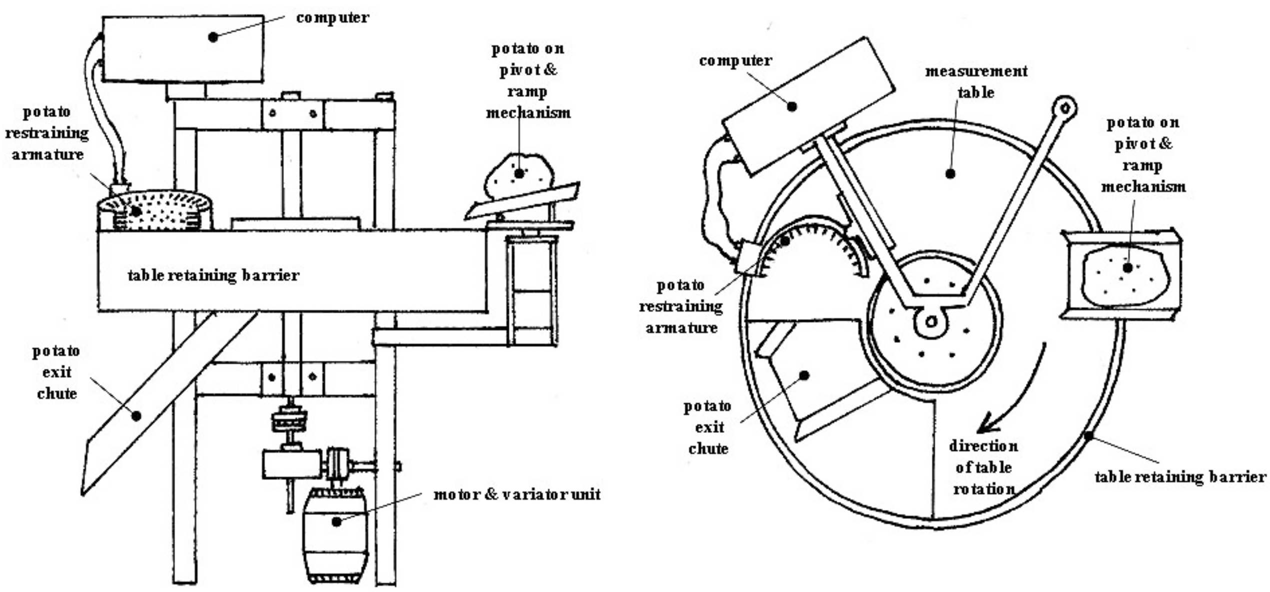

Fig. 1. Scheme of the test apparatus side view (left) and from above (right)

and horticultural conveyer belting in the UK. The nature of the asperities present on 2 × 1 mm transverse sections of the test surfaces observable at 400× magnification was: 13.2 asperities/ml of approximately 100 mm for plastic, 4.6/ml of approximately 30 mm for rubber, with none observable on steel.

During testing each tuber was located by the table rotation in a "C" shaped restraining armature and held static while the table continued to rotate. After three-quarters of a rotation the tuber fell through an aperture onto a chute which operated the solenoid actuator mechanism. The forces produced on the restraining armature were measured in both the horizontal and vertical planes to triangulate those in action (initial validation indicated no requirement for the estimation of lateral strain). Force was measured by RS632-736 2 kg load cells, calibrated with known masses (± 2 g) mounted on the axes of the restraining device, which produced digitalised signal outputs to a computer programmed to translate the signal into N. The force produced by the rotating table and transferred through the tuber against which the restraint was acting was calculated through vector analysis and used to determine μ.

Two thousand cured and stored Cara potatoes (a commonly grown UK cultivar) (sized 50 to 64 mm) were used for each of the surface materials tested (500/surface condition) and were allowed to warm up to 8 to 10°C prior to the tests, this temperature being an indicative point in tuber tissue elastic stress response (Hyde et al. 1997). Tubers were treated sequentially in the following manner: (a) left dry and dirty (unwashed); (b) wetted by sprinkling with water until the dirt tare lost friability and became adhesive to other surfaces; (c) ashed (all dirt removed) and allowed to drain freely; (d) washed and dried (water removed by evaporation in a cold store).

An initial test was carried out using plastic spheres (mass 205 g, diameter 74 mm) to validate the method and examine the depth of deformation of the surfaces as measured by dial gauge micrometer. The mean dynamic coefficient of friction of the spheres on mild steel was 0.48 ± 0.003, and the depression of the test surfaces under static loading was 2.00 mm for rubber, 0.17 mm for plastic and 0.003 mm for steel, these results being qualitatively in agreement with the moduli of elasticity of these materials.

The experiment was arranged in a three way factorial design with three levels of treatment for machinery surface and two for surface moisture and surface dirt. Statistical analysis was done with Unistat v. 4.00 (Unistat, Ltd., London, UK) using classical approach, multi-factorial ANOVA, with all treatment combinations separated at single factorial level to enable a Tukey-HSD test to be used to assist in the interpretation of the interactions present. All effects described are at the $P < 0.05$ level.

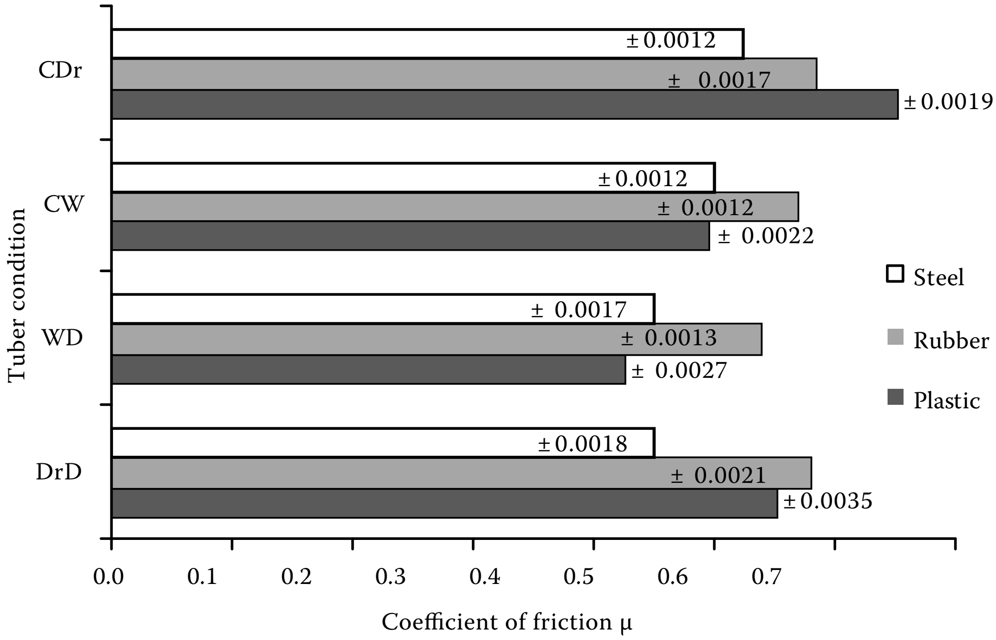

Fig. 2. Mean coefficient of friction values (± SE) for dry dirty (DrD), wet dirty (WD), clean wet (CW) and clean dry (CDr) potatoes tested on mild steel, rubber and plastic surfaces

RESULTS AND DISCUSSION

Results are given in Fig 2. Steel had the lowest overall mean μ value and a coefficient of variation (*CV*) of 9.8%. Rubber gave higher values, but had the lowest overall *CV* (9.3%). For plastic the results were more variable, giving the lowest COF (for wet dirty tubers) and the highest (for clean dry tubers); the *CV* was 19.2%. Kurtosis (–0.18) and skewness (0.09) of the data indicated normality. Statistical analysis of the treatment hierarchy by three-factorial ANOVA indicated that all treatments and 2-way interactions had a significant effect on the COF, except the 2-way interaction dirt × wet (P = 0.370). Where multiple factorial treatment combinations were re-analysed as individual groups by single factorial ANOVA, all groups were significantly different one another, except there was no difference between dirty samples on steel if wet or dry; clean wet tubers on steel could not be distinguished from clean tubers, wet or dry, on rubber; and there was no difference between clean wet tubers on plastic or steel.

The presence of soil in all cases caused a reduction in μ and an increase in *CV*. Moisture also reduced μ, presumably acting as a lubricant to separate asperities of the surfaces (Mohsenin 1965). However, there was no straightforward pattern in the way in which different test surfaces responded to the different tuber conditions. The elasticity of the surface and its asperities appeared to be of considerable importance. Rubber has high elasticity and small asperities, factors which discourage soil accumulation or fluidisation between surfaces and encourage a high contact area; plastic has larger asperities which will individually offer high frictional resistance.

In general, steel offered lower COF values regardless of tuber condition. Results with rubber were the most consistent, suggesting that it would be the most appropriate material for handling tubers in a range of conditions. For steel and rubber the results presented here match those of Schaper and Yaeger (1992) who used 25 kg samples of tubers more than one deep, and a substantially different apparatus. The high *CV* with plastic indicated that tuber flow is likely to be more variable with this material, although it was good for use with clean, dry tubers.

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