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Effect of Sliding Speed, Abrasion Surface and Normal Load on Coefficient of Friction of Grapefruit (*Citrus paradisi*)

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Star Ruby grapefruits were tested using a linear sliding friction test device connected to a Lloyd material testing machine, a data acquisition system and a personal computer. The tests were carried out with four replications per treatment combination under controlled variable parameters. Controlled variable parameters were sliding speed, abrasion surface and normal load. The peak static and average dynamic coefficients of friction against four abrasion surfaces (aluminum, plastic, corrugated cardboard and galvanized sheet) were measured at four sliding speeds (50, 100, 250 and 500 mm min^{-1}) and three normal loads (20, 30 and 40 N). Analysis of variance (ANOVA) results showed that abrasion surface for both peak static and average dynamic, and normal load for only average dynamic coefficient of friction significantly affected the coefficient of friction, respectively. The effect of sliding speed on both coefficients of friction was not statistically significant. The coefficient of friction tended to increase or decrease depending on abrasion surface and normal load. The highest peak static and average dynamic coefficient of friction were found in the case of galvanized sheet by 500 mm min^{-1} and galvanized sheet by 50 mm min^{-1} combinations, respectively. The results of this study could be used for protecting products against abrasion damage.

Key Words: abrasion surface, coefficient of friction, grapefruit, sliding speed

Abbreviations: β_0, β_1, β_2 – regression coefficients; AS – abrasion surface; COF – coefficient of friction; COF_D - average dynamic coefficient of friction; COF_S – peak static coefficient of friction; F – friction force, N; NL – normal load, N; SS – sliding speed, mm min^{-1}; X_1, X_2 – independent variables; Y – dependent variables

INTRODUCTION

Fruits are attractive and nutritional foods due to their color, unique taste and smell, enriched minerals, vitamin and other beneficial components. Cultivated citrus fruits may be derived from as few as four ancestral species. Numerous natural and cultivated origin hybrids include commercially important fruits such as the orange, grapefruit, lemon, some limes and some tangerines. The grapefruit (*Citrus paradisi*) is one of the popular fruits belonging to the Citrus family, and is primarily produced in the United States, China and Brazil. However, there are a few other countries which are also large grapefruit producers such as Spain, Turkey, South Africa and Italy.

Turkey is the 8th largest citrus-producing country with an annual production of about 2.9 million tons constituting 6% of the world production. Most of the grapefruits are produced in the Mediterranean region such as Mersin, Adana, Antalya and Hatay in Turkey.

The grapefruit has higher international market potential. However, physical damages such as oleocellosis or oil spot are commonly caused by abrasion due to incorrect handling. These injuries decrease the quality and physical appearance as well as result in shorter storage life and unexportable fruits. Mechanical damage is due to one or more types of loading: compression, impact and vibration, as can be seen in normal citrus packing lines. Surface abrasion, or friction against machine parts, is one of the main causes of mechanical injuries during incorrect handling (Singh et al. 2004). For this reason, the acquisition of knowledge about coefficient of friction (COF) is important in the design of production and handling equipment with storage structures.

Despite the many researches on the COF of several fruits, there is limited information about the COF of grapefruit. Miller (1987) investigated the physical properties for the postharvest handling of Florida citrus and reported that the dynamic coefficient of friction (COF_D) for Florida