Drug Development and Industrial Pharmacy, 22(7), 667-671 (1996)

The Effect of Wax and Water on Extrusion Forces Using an Instrumented Miniextruder

Nathaniel O. Iloañusi and Joseph B. Schwartz

Department of Pharmaceutics, Philadelphia College of Pharmacy and Science, Philadelphia, Pennsylvania 19104

ABSTRACT

An instrumented miniextruder is described and was used to evaluate the effect of wax and water on forces during the extrusion process. Samples as small as 50 g were evaluated. Microcrystalline cellulose (Avicel® PH-101) and acetaminophen were formulated to prepare spheres using methods of extrusion and spheronization. A commercially available wax product, Compritol® (glycerol behenate, N.F.), was added to the formula in levels of 10%, 30%, and 50%, and formulations were granulated with distilled water. As the amount of distilled water or the level of wax was increased in the formulations, a decrease in measured extrusion force was observed. This effect on extrusion forces seemed to be influenced more by the addition of wax than by the level of water. In fact, it was noted that the wax alone decreased the extrusion forces. A comparison between the miniextruder's force readings and power consumption data from an instrumented NICA (model E-140) extruder indicates similar trends.

INTRODUCTION

Extrusion and spheronization technology is a common method of producing beads or pellets (1). To characterize the extrusion and spheronization method of producing beads, the extruder has been instrumented to monitor the process where the wet mass is shaped into short rods (3-6). Data obtained from the instrumented extruder were used to determine the extrudability of a given formulation or to assess the flow and spheronization properties of particular mixtures (1,2). This paper describes an instrumented miniextruder, jointly designed (with SMI Inc., Pittstown, NJ), in principle after the ram extruder. The use of the miniextruder makes it possible to evaluate the suitability of materials for the extrusion-spheronization process on a very small scale. Samples as small as 50 g were evaluated. A sample was extruded and the forces were monitored to characterize the extrusion process. The effect of wax and water on the forces of extrusion of a microcrystalline cellulose-acetaminophen formulation was evaluated. The objectives were to determine the influence of wax and water on the extrusion forces, and to determine whether the effect was complementary or opposing.

MATERIALS AND EQUIPMENT

Extrusion Force Measurement

Figure 1 is a schematic diagram of the miniextruder. The detailed setup of the system is shown in Fig. 2. The miniextruder consists of a power box which controls the speed of the anvil. In addition to the speed control button, the power box also has an up-down switch to control the direction of the anvil's movement. The cylinder, the base (screen holder), and the screen are removable. The sample is placed in the cylinder unit. This unit is placed inside a base which has been fitted with a 1.5-mm screen. This assembly is then coupled to the supporting frame of the extruder. The load cell encircles the cylinder/screen assembly and is connected to a DC battery and a recorder. As power is turned on the anvil travels downward into the cylinder. The speed of the anvil is controlled by the motor. When the anvil makes contact with the sample, the screen is pressed against the load cell and the resistance of the sample is monitored. The output from the load cell is collected by a recorder. The output is the force of extruding the granulation through the screens.

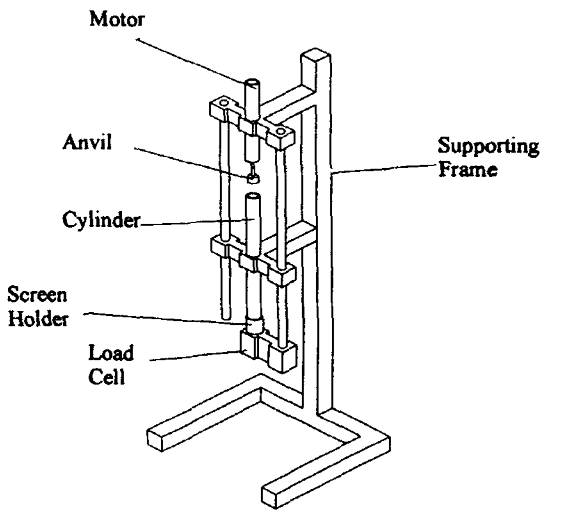

Figure 1. Schematic diagram of the miniextruder.

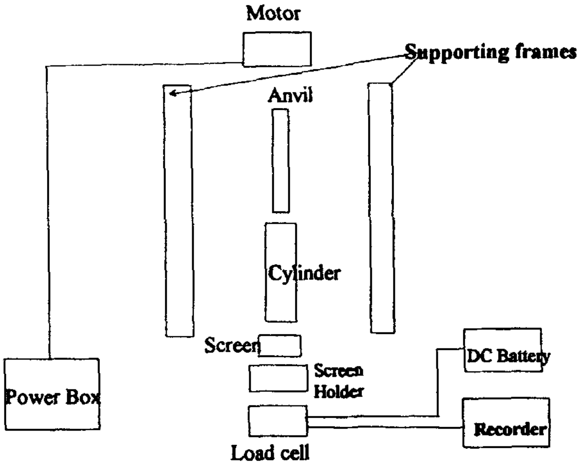

Figure 2. Schematic setup of the miniextruder.

Materials and Methods

Microcrystalline cellulose (Avicel® PH-101, FMC Corporation, Princeton, NJ) and acetaminophen (APAP, Penco of Lyndhurst Inc., Lyndhurst, NJ) were formulated to prepare spheres using the methods of wet granulation, extrusion and spheronization. The acetaminophen level was kept constant at 10% throughout the study. The wax, Compritol® (glycerol behenate, N.F., Gattefossé, France), was added to the formulation in levels of 10%, 30%, and 50%. A mixture of 10% APAP and microcrystalline cellulose (MCC) without wax was utilized as a control formulation. The mixtures of wax, MCC, and APAP were granulated with varying levels of purified water. The powders were dry blended in a kitchen aid mixer for 3 min and water was added over the next 2 min. The blade was stopped and the mixing bowl was scraped to ensure proper mixing; then mixing was continued for an additional 3 min.

The granulation was extruded through a Luwa extruder (Model EXDS-60, LUWA Corporation, Charlotte, NC) fitted with 1.5-mm twin screens and operated at 50 rpm. The extrudate was spheronized in the marumerizer (Model Q-230, LUWA Corporation, Charlotte, NC) operated at 1000 rpm and fitted with a 2-mm scored friction plate. The spheres were collected after a 60-sec residence time and dried in a hot air oven.

In addition to this normal extrusion and spheronization process, a sample of each granulation was extruded with the miniextruder through a 1.5-mm screen. The extrusion forces were monitored from the time the anvil made contact with the sample until the extrusion cycle was complete.

Extrusion Force Measurement

The trace of the recorder describes the forces generated by the formulation during the extrusion process. The peak forces of extrusion were used to compare formulations. The samples of each formulation were collected and the peak forces of extrusion were averaged.

RESULTS AND DISCUSSION

The Extrusion Cycle

Figure 3 shows a typical plot of an extrusion cycle. The anvil enters the cylinder and an initial baseline of the transducer is recorded. As the anvil makes contact with the granulation, the extrusion cycle begins. As the anvil densifies the granulation toward the screen, the force output increases proportionally. The resistance of the sample to extrude is detected and produces erratic forces. At this point, the granulation begins to be extruded through the screen. A maximum force is reached during the extrusion of the granulation. The anvil continues movement toward the screen and a reduction in force is detected. At this point the extrusion cycle is complete and the switch is turned to the up position, pulling the anvil out of the cylinder and returning the recorder to the baseline. The width of the peak is dependent on the volume of the sample placed in the cylinder, while the resistance area is dependent on the consistency of the granulation. If the granulation sample is dry, the output is more erratic in this area of the peak, suggesting more resistance of the granulation against the extrusion screen.

The Effect of Water on Extrusion Force

The maximum extrusion force was calculated as the mean of three trials. The maximum extrusion force was plotted against the percent water level used to granulate each formulation. The percentage of water was calculated based on total solid weight. As the amount of purified water used to granulate increased, the maximum extrusion forces decreased (Fig. 4). A reduction in the maximum extrusion force occurs due to water increasing the plasticity of the granulation. With increased plasticity, the granulation deforms with little resistance and requires less force for extrusion. The formulations are compared in Fig. 5. The control is the formulation without wax, which is compared against the formulations containing wax at different levels.

The Effect of Wax on Extrusion Force

A decrease in maximum extrusion force at a specific water level was observed as the level of wax in the

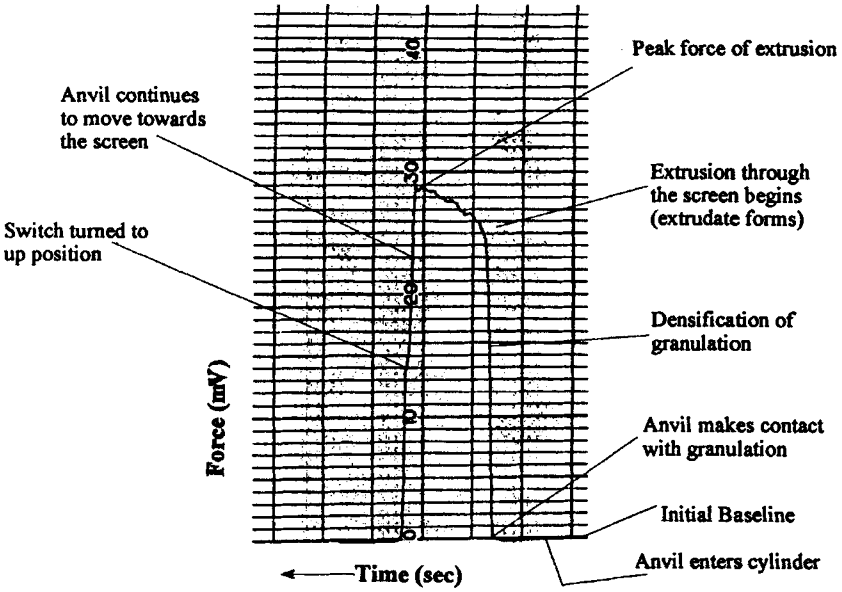

Figure 3. Typical plot of extrusion cycle.

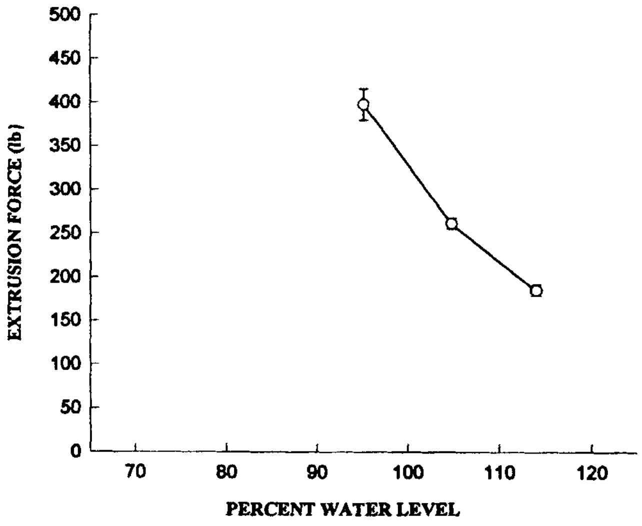

Figure 4. Water level vs. maximum extrusion force during the extrusion of 10% APAP and Avicel PH-101 powder mixture (N = 3).

formula was increased (Fig. 5). For example, at 95% water level, the control formulation generated an maximum extrusion force of 398 lb, 10% wax 350 lb, 30% wax 137 lb, and 50% wax only 48 lb. Compared to the control, the addition of wax even as low as 10% level showed a significant decrease in extrusion force, suggesting that wax has a role in plasticizing the granulation.

This effect on extrusion forces (and plasticity of the wet granulation) seemed to be influenced more by the addition of wax than by the level of water used to granulate. At the same water level, the differences between wax levels were statistically significant using the t test. The studies indicate that less force is required to form extrudate as more water is used to granulate, and even much less force is required when wax is added to the formulation. It also shows that with the miniextruder, the extrusion and spheronization characteristics of a given formula can be evaluated even when a very limited quantity is available.

The extrusion results from the instrumented miniextruder were compared to that from an instrumented NICA (model E-140) extruder. The instrumentation of the NICA extruder measures the power consumption rather than extrusion force. The power value is related to the work done by the machine to extrude the granulation (Fig. 6). The comparisons between the miniextruder's average maximum force of extrusion and power consumption data from the NICA model extruder indi-

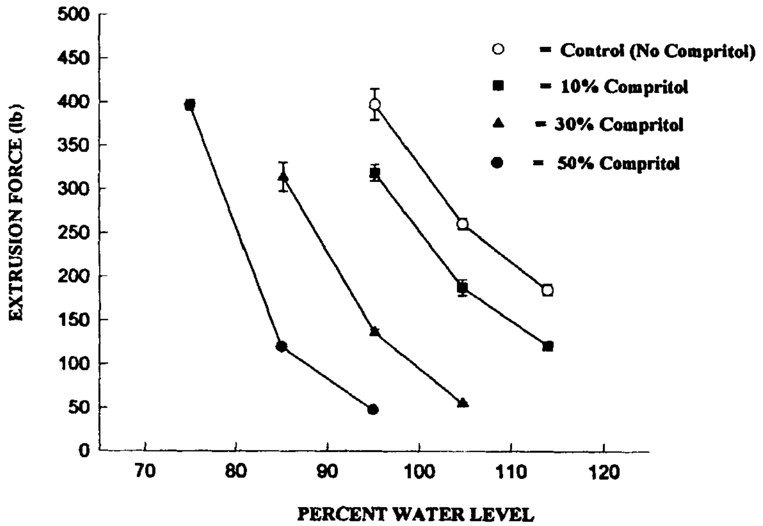

Figure 5. Water level vs. maximum extrusion force during the extrusion of 10% APAP, (*) Compritol, and Avicel PH-101 powder mixture (N = 3).

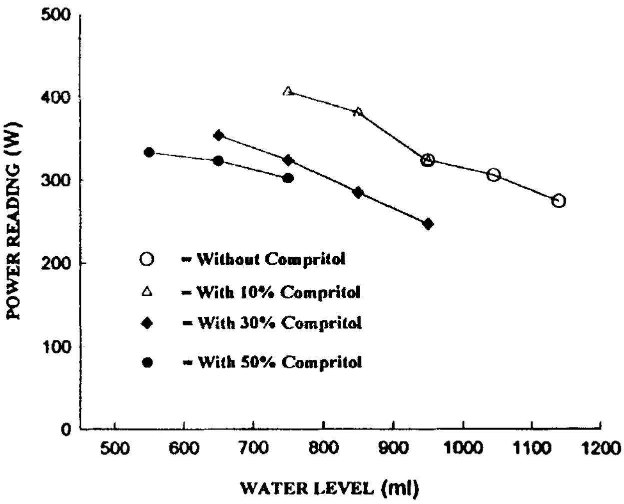

Figure 6. Water level vs. power reading during the extrusion of 10% APAP, (*) Compritol, and Avicel PH-101 powder mixture.

cate similar trends with respect to the effect of wax and water on the extrusion forces.

ACKNOWLEDGMENT

The authors would like to thank the Specialty Measurements International Inc. (SMI) for building the miniextruder used in this study, and FMC Corporation for the use of their NICA extruder and Avicel® PH-101.

REFERENCES

1. R. E. O'Connor and J. B. Schwartz, Extrusion and spheronization technology, in *Pharmaceutical Pelletization Technology* (I. Ghebre-Sellassie, ed.), Marcel Dekker, New York, 1989, pp. 187–216.
2. L. Baert and J. P. Remon, Influence of amount of granulation liquid on the drug release rate from pellets made by extrusion-spheronization, Int. J. Pharm., 95, 135–141 (1993).
3. J. A. C. Elbers, H. W. Bakkenes, and J. G. Fokkens, Effect of amount and composition of granulation liquid on mixing, extrusion and spheronization, Drug. Dev. Ind. Pharm., 18, 501–517 (1992).
4. K. E. Fielden, J. M. Newton, and R. C. Rowe, A comparison of the extrusion and spheronization behaviour of wet powder masses processed by a ram extruder and a cylinder extruder, Int. J. Pharm., 81, 225–233 (1992).
5. R. D. Shah, M. Kabadi, D. G. Pope, and L. L. Augsburger, Physicomechanical characterization of the extrusion-spheronization of the extruder, Pharm. Res., 11, 355–360 (1994).
6. C. Veraet, L. Baert, and J. P. Remon, Extrusion-spheronization: A literature review, Int. J. Pharm., 116, 131–146 (1995).