

## INTISARI

*Bone fracture* yang disebabkan oleh trauma, penyakit, dan penuaan mendorong pengembangan rekayasa jaringan tulang melalui *biomedical bone scaffold*. *Stainless steel 316L* (SS316L) banyak digunakan sebagai material *scaffold* karena biokompatibilitas dan kekuatannya, namun perbedaan sifat mekanis dengan tulang dapat menyebabkan *stress shielding*. Untuk mengurangi fenomena tersebut, SS316L difabrikasi dalam bentuk berpori menggunakan *space holder method*, di mana struktur pori dan sifat mekanis *scaffold* sangat dipengaruhi oleh tekanan kompaksi dan fraksi volume *space holder*. Tekanan kompaksi yang berlebihan berpotensi mengubah bentuk dan distribusi pori sehingga memengaruhi performa *scaffold*. Penelitian ini bertujuan untuk mengkaji pengaruh tekanan kompaksi dan fraksi volume *carbamide* terhadap karakteristik morfologi *green body*, struktur pori, dan sifat mekanis *scaffold* SS316L.

*Scaffold* difabrikasi menggunakan metode *space holder* dengan variasi campuran fraksi volume *carbamide* sebesar 40, 50, dan 60 vol%. Campuran serbuk SS316L/*carbamide* dikompaksi dengan variasi tekanan yang mendekati *yield* dan tekanan yang melebihi *yield*. Analisa kompaksi dengan model kompaksi Heckel dilakukan untuk mengetahui tekanan *yield* dari campuran SS316L/*carbamide*. Proses *removal space holder* dilakukan dengan teknik *water leaching* dan proses *sintering* dilakukan pada suhu 1000 °C dengan waktu penahanan selama 1 jam. Evaluasi morfologi dilakukan dengan pengamatan makro dan mikro struktur menggunakan *digital microscope* dan SEM. Uji tekan menggunakan *universal testing machine* dilakukan untuk mengevaluasi sifat mekanis *scaffold*.

Hasil penelitian menunjukkan bahwa peningkatan tekanan kompaksi meningkatkan densifikasi *green body*, di mana tekanan mendekati *yield pressure* ( $P_y$ ) menghasilkan *scaffold* dengan pori yang relatif teratur, konektivitas baik, dan *strut* yang baik, dibanding tekanan jauh di atas  $P_y$ . Secara mekanis, peningkatan tekanan kompaksi cenderung meningkatkan kekuatan *ultimate* dan menurunkan modulus elastisitas. Sementara itu, peningkatan fraksi volume *carbamide* secara signifikan meningkatkan porositas, ukuran, dan interkonektivitas pori, tetapi menurunkan kekuatan mekanik *scaffold*. Sifat mekanik *scaffold* keseluruhan masih berada dalam rentang sifat mekanik tulang *cancellous*, sehingga berpotensi digunakan sebagai *bone scaffold* untuk aplikasi implan dengan beban ringan hingga menengah.

**Kata kunci:** *Stainless Steel 316L*, *Bone Scaffold*, Metode *Space Holder*, *Carbamide*, Kompaksi, Heckel Model.

## ABSTRACT

*Bone fractures caused by trauma, disease, and aging have driven the development of bone tissue engineering through biomedical bone scaffolds. Stainless steel 316L (SS316L) is widely used as a scaffold material due to its biocompatibility and high strength, however, the mismatch in mechanical properties between SS316L and natural bone may lead to stress shielding. To mitigate this phenomenon, SS316L was fabricated in a porous form using the space holder method, in which the pore structure and mechanical properties of the scaffold are strongly influenced by the compaction pressure and the volume fraction of the space holder. Excessive compaction pressure may alter the pore shape and distribution, thereby affecting the scaffold performance. This study aims to investigate the effects of compaction pressure and carbamide volume fraction on the morphological characteristics of the green body, pore structure, and mechanical properties of SS316L scaffolds.*

*Scaffolds were fabricated using the space holder method with carbamide volume fractions of 40, 50, and 60 vol%. The SS316L/carbamide powder mixtures were compacted at pressures close to the yield pressure and at pressures exceeding the yield pressure. Compaction analysis based on the Heckel model was conducted to determine the yield pressure of the SS316L/carbamide mixtures. The space holder was removed using a water leaching technique, and sintering was carried out at 1000 °C with a holding time of 1 hour. Morphological evaluation was performed through macro and microstructural observations using a digital microscope and scanning electron microscopy (SEM). Compressive testing using a universal testing machine was conducted to evaluate the mechanical properties of the scaffolds.*

*The results show that increasing compaction pressure enhances green body densification, where compaction near the yield pressure ( $P_y$ ) produces scaffolds with relatively uniform pores, good interconnectivity, and well-formed struts compared to compaction at pressures far above  $P_y$ . Mechanically, higher compaction pressure tends to increase the ultimate compressive strength while reducing the elastic modulus. Meanwhile, increasing the carbamide volume fraction significantly increases porosity, pore size, and pore interconnectivity, but decreases the mechanical strength of the scaffolds. Overall, the mechanical properties of the scaffolds fall within the range of cancellous bone, indicating their potential suitability as bone scaffolds for low to medium load implant applications.*

**Keyword:** *Stainless Steel 316L, Bone Scaffold, Space Holder Method, Carbamide, Compaction, Heckel Model.*